KEITHLEY

Model 236/237/238
Source Measure Units
Operator's Manual

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Model 236/237/238
Source Measure Units

Operator's Manual

Contains Operating and Servicing Information

KEITHLEY

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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KEITHLEY

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Model 236 Source Measure Unit
Model 237 High Voltage Source Measure Unit
Model 238 High Current Source Measure Unit
Operator's Manual

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Hiermit wird bescheinigt, (daβ)/das `MODEL 236/237/238 SOUCE MEASURE UNIT` in Ubereinstimmung mit den Bestimmungen der Vfg 1046/1984 funk-entstort ist. Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerates angezeigt und die Berechtigung zur Uberprufung der Serie auf Einhaltung der Bestimmungen eingeraumt.

Die Einhaltung der betreffenden Bestimmungen setzt vordus, daβ, (dass) geschirmte Meβleitungen verwendet werden. Fur die Beschaffung richtiger Meβleitungen ist der Betreiber verantwortlich.

DIESES GERAET WURDE SOWOHL EINZELN ALS AUCH IN EINER ANLAGE, DIE EINEN NORMALEN ANWENDUNGSFALL NACHBILDET, AUF DIE EINHALTUNG DER FUNK-ENTSTOERBESTIMMUNGEN GEPRUEFT. EST IS JEDOCH MOEGLICH, DASS DIE FUNK-ENTSTOERBESTIMMUNGEN UNTER UNGUENSTIGEN UMSTAENDEN BEI ANDEREN GERAETEKOMBINATIONEN NICHT EINGEHALTEN WERDEN. FUER DIE EINHALTUNG DER FUNK-ENTSTOERBESTIMMUNGEN SEINER GESAMTEN ANLAGE, IN DER DIESES GERAET BETRIEBEN WIRD, IST DER BETREIBER VERANTWORTLICH.

Keithley Instruments, Incorporated

CERTIFICATE BY MANUFACTURER/IMPORTER

This is to certify that the `MODEL 236/237/238 SOURCE MEASURE UNIT` is shielded against radio interference in accordance with the provisions of Vfg 1046/1984. The German Postal Services have been advised that this device is being put on the market and that they have been given the right to inspect the series for compliance with the regulations.

Compliance with applicable regulations depends on the use of shielded cables. It is the user who is responsible for procuring the appropriate cables.

THIS EQUIPMENT HAS BEEN TESTED CONCERNING COMPLIANCE WITH THE RELEVANT RFI PROTECTION REQUIREMENTS BOTH INDIVIDUALLY AND ON SYSTEM LEVEL (TO SIMULATE NORMAL OPERATION CONDITIONS). HOWEVER, IT IS POSSIBLE THAT THESE RFI REQUIREMENTS ARE NOT MET UNDER CERTAIN UNFAVORABLE CONDITIONS IN OTHER INSTALLATIONS. IT IS THE USER WHO IS RESPONSIBLE FOR COMPLIANCE OF HIS PARTICULAR INSTALLATION.

Keithley Instruments, Incorporated

SAFETY WARNINGS

The following safety warnings should be observed before using Model 236/237/238 Source Measure Units.

The Model 236/237/238 Source Measure Unit is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the operator's manual carefully before using the instrument.

Exercise extreme caution when a shock hazard is present. Lethal voltages may be present on the test fixture or the Source Measure Unit connector jacks. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS or 42.4V peak are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the Source Measure Unit, test fixture, test cables or any other instruments while power is applied to the circuit under test. Turn off all power and discharge any capacitors before connecting or disconnecting cables or jumpers. Also, keep the test fixture lid closed while power is applied to the device under test. Safe operation requires the use of the lid interlock.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Do not exceed the maximum signal levels of the test fixture, as shown on the rear panel and as defined in the specifications and operation section of the instruction manual.

Connect the ⏚ screw of the test fixture to safety earth ground using #18 AWG or larger wire (supplied accessory).

Instrumentation and accessories should not be connected to humans.

The ⚡ symbol on a Model 237 indicates that 1000V or more may be present on the terminals. Refer to the Model 236/237/238 Operator's Manuals for detailed operation information.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

For multiple unit interlocked test systems, either keep all Model 236/237/238s powered on, or turn them all off.

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PRÉCAUTIONS DE SÉCURITÉ

Il faut observer les précautions de sécurité suivantes avant d'utiliser les appareils de mesure de source 236/237/238.

L'appareil de mesure de source du modèle 236/237/238 doit être utilisé par des personnes qualifiées qui reconnaissent les risques d'électrocution et sont familières avec les précautions de sécurité nécessaires pour éviter des blessures possibles. Il faut lire le manuel de l'opérateur avec soin avant d'utiliser l'instrument.

Il faut faire extrêmement attention quand il y a des risques d'électrocution. Des tensions mortelles peuvent être présentes dans le dispositif de test ou dans les fiches de connecteurs de l'appareil de mesure de source. L'institut National Américain des Normes (ANSI) dit qu'il y a un risque d'électrocution quand des tensions supérieures à 30 V RMS ou 42.4 V de pointe sont présentes. **Une bonne habitude de sécurité est de s'attendre à des tensions dangereuses avant de mesurer un circuit inconnu.**

Avant chaque utilisation, il faut vérifier que les câbles de connexion, les cordons de test et les fils de connexion ne soient pas usés, fissurés ou cassés.

Pour le maximum de sécurité, ne pas toucher les connecteurs, le dispositif de test ou les câbles de test de l'appareil de mesure de source ou tout autre connecteur d'instrument quand le circuit à essayer est sous tension. Mettre sur l'arrêt toutes les alimentations et décharger tous les condensateurs avant de brancher ou débrancher les câbles ou les fils. Il faut aussi maintenir fermé le couvercle du dispositif de test pendant le test de l'appareil. Il faut verrouiller le couvercle pour obtenir une utilisation sans danger.

Ne pas toucher n'importe quel objet qui pourrait fournir un passage au côté commun du circuit à essayer ou à la masse de l'alimentation. Il faut toujours faire les mesures avec des mains sèches en se tenant sur une surface sèche et isolée capable de supporter la tension à mesurer.

Ne pas dépasser les niveaux maximum de signaux de l'instrument, comme montré sur le panneau arrière et comme indiqué dans la section des données techniques et des opérations du manuel de l'instrument.

Les instruments et les accessoires ne doivent pas être branchés sur des personnes.

Le symbole ⚡ sur le modèle 237 indique que 1000 V ou plus peuvent être présents dans les terminaux.

Avec le détecteur éloigné en marche, un cordon de détection ouvert peut produire des tensions mortelles à OUTPUT HI et GUARD. Cette tension peut causer des blessures ou la mort et endommager les circuits extérieurs. Il faut toujours s'assurer que les cordons de détection soient correctement branchés avant de mettre en marche le détecteur éloigné. NE JAMAIS changer les branchements sous tension. Il faut s'assurer de toujours décharger et/ou débrancher les sources externes d'alimentation.

Pour les dispositifs de test à plusieurs appareils verrouillés, il faut garder tous les modèles 236/237/238 soit tous en marche ou soit tous arrêtés.

SOMMAIRE DES COMMANDES

LOCAL (LOCAL) : Met l'appareil en fonctionnement local et rétablit le fonctionnement des touches du panneau frontal.

GROUPE DE SOURCE

OPERATION (OPERATE) : Met l'appareil en position de fonctionnement ou d'attente.

MESURE SOURCE (SOURCE MEASURE) : Choisit la tension de source et mesure l'intensité ou choisit l'intensité de la source et mesure la tension.

FONCTION (FUNCTION) : choisit le fonctionnement en courant continu ou en balayage.

CONFORMITÉ (COMPLIANCE) : Vérifie le niveau de conformité et mesure la plage. Changer le niveau actuel et la plage en utilisant le commutateur rotatif ou le clavier, ensuite appuyer sur ENTER.

GROUPE DE MESURES

TEMPS (TIME) : Vérifie la période d'intégration. Changer la sélection actuelle en appuyant sur les boutons de SELECT, ensuite appuyer sur ENTER.

SAUVEGARDE (SUPPRESS) : Sauvegarde la conversion suivante comme ligne de base. Les lectures suivantes seront la différence entre la valeur supprimée et le niveau réel du signal.

FILTRE (FILTER) : Affiche l'état du filtre de mesure. Changer la quantité de filtration en appuyant sur les boutons de SELECT, ensuite sur ENTER.

AUTOPLAGE (AUTORANGE) : Permet à l'appareil de se mettre dans la plage avec la plus grande sensibilité pour faire une mesure.

GROUPE DE BALAYAGE

CREER (CREATE) : Choisit un balayage et définit ses paramètres. Utiliser les boutons de SELECT pour changer le type de balayage, ensuite appuyer sur ENTER. Utiliser le commutateur rotatif pour afficher les paramètres de balayage et le clavier pour les changer.

MODIFIER (MODIFY) : Affiche les valeurs de la source et de délais des points de balayage sauvegardés. Utiliser le bouton pour choisir le point de balayage, les boutons SELECT pour choisir la valeur de source et de délais, le clavier et ENTER pour changer les valeurs. Si la valeur de la source a changé, utiliser les boutons SELECT et ENTER pour changer la plage de la source.

AJOUT (APPEND) : Ajoute un balayage à un balayage existant. Appuyer sur APPEND fait afficher le balayage actuel et ses paramètres. Utiliser les boutons SELECT pour changer le type de balayage, ensuite appuyer sur ENTER. Utiliser le commutateur rotatif pour afficher les paramètres de balayage et le clavier pour les changer.

RAPPEL (RECALL) : Affiche les paramètres de la source, les valeurs des mesures et la durée pour chaque point de balayage. Utiliser le commutateur rotatif pour choisir le point et les boutons SELECT pour afficher les paramètres. Affiche seulement les valeurs de la source et du délais avant de faire le balayage.

GROUPE DE DÉCLENCHEMENT

PRÉPARATION (SETUP) : Vérifie l'état actuel du déclenchement. Utiliser le commutateur rotatif pour afficher les paramètres, les touches SELECT et ENTER pour changer les paramètres.

MANUEL (MANUAL) : Le voyant de déclenchement MANUAL clignotant indique qu'une stimulation de déclenchement est nécessaire (appuyer sur le bouton MANUAL, une commande de déclenchement sur le bus IEEE-488 ou une entrée externe de déclenchement).

GROUPE D'ENTRÉE DE DONNÉES

Commutateur rotatif : Commande l'affichage de différents paramètres de fonctionnement, règle les valeurs de la source et de conformité, et quand en RECALL, commande l'affichage des données de balayage.

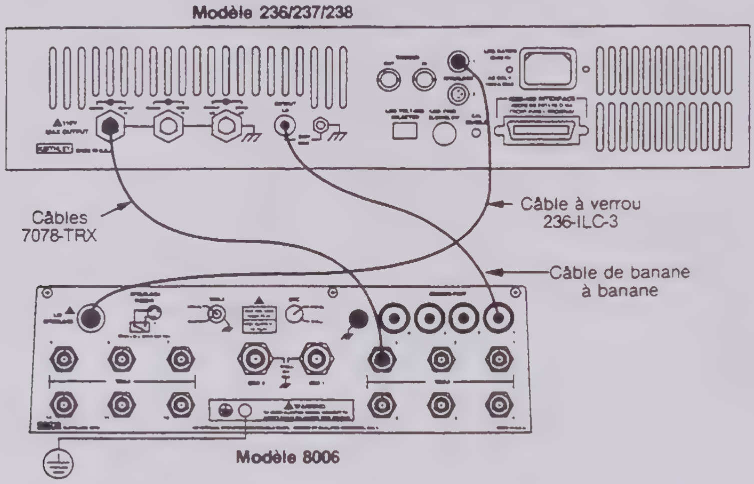
CHOIX (SELECT) : Ces boutons choisissent les paramètres de fonctionnement de remplacement et, quand en RECALL, commandent l'affichage des données de balayage.

Clavier : Toutes les touches du clavier (sauf MENU) entrent ou annulent les données numériques.

MENU (MENU) : Utilisé pour vérifier ou changer les conditions suivantes de fonctionnement: délais du courant continu (0 à 65 secondes), délais d'implicite (marche/arrêt), détection (locale/éloignée), fréquence de l'alimentation (50 Hz/60 Hz) et l'adresse IEEE-488 (0 à 30 secondes). Aussi utilisé pour faire les auto-tests.

Branchements typiques

Branchements de détection locale en utilisant le dispositif de test modèle 8006


Modèle 236/237/238
Câbles 7078-TRX
Câble à verrou 236-ILC-3
Câble de banane à banane
Modèle 8006

ATTENTION : Brancher à une masse de sécurité.

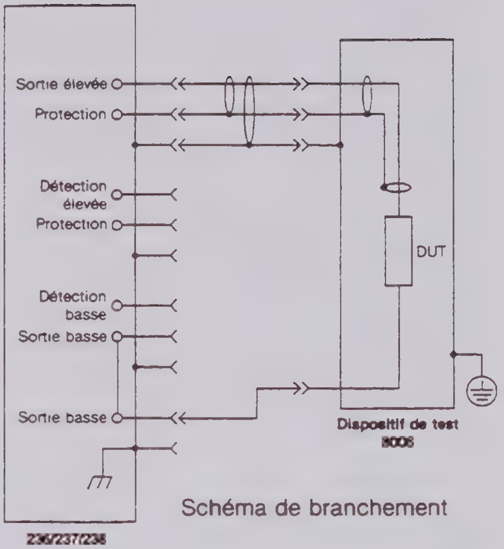
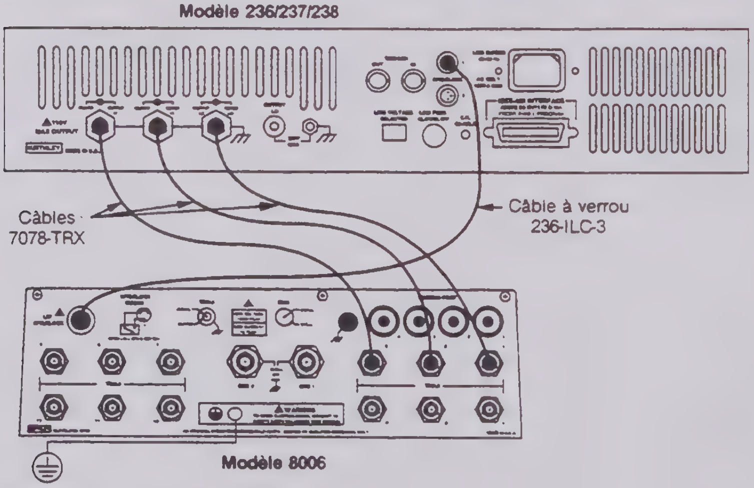

Sortie élevée
Protection
Détection élevée
Protection
Détection basse
Sortie basse
Sortie basse
DUT
Dispositif de test 8006
236/237/238

Schéma de branchement

Branchements de détection éloignée en utilisant un dispositif de test modèle 8006


Modèle 236/237/238
Câbles 7078-TRX
Câble à verrou 236-ILC-3
Modèle 8006

ATTENTION : Brancher à une masse de sécurité.

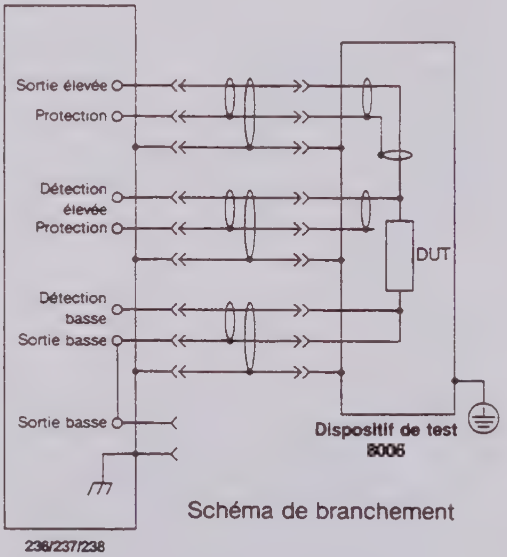
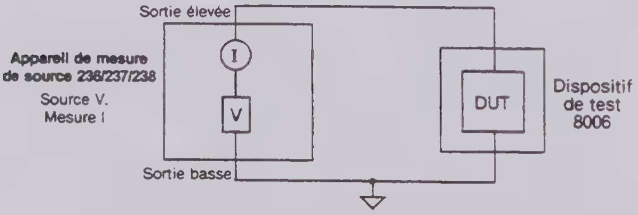
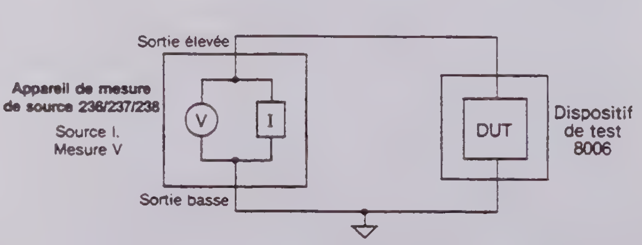

Sortie élevée
Protection
Détection élevée
Protection
Détection basse
Sortie basse
Sortie basse
DUT
Dispositif de test 8006
236/237/238

Schéma de branchement

Circuits équivalents


Sortie élevée
Appareil de mesure de source 236/237/238
Source V. Mesure I
I
V
Sortie basse
DUT
Dispositif de test 8006


Sortie élevée
Appareil de mesure de source 236/237/238
Source I. Mesure V
V
I
Sortie basse
DUT
Dispositif de test 8006

SICHERHEITSHINWEISE

Vor dem Gebrauch der Quellenmeßgeräte Modelle 236/237/238 beachten Sie bitte folgende Sicherheitshinweise.

Das Quellenmeßgerät Modell 236/237/238 ist für den Gebrauch durch qualifiziertes Personal gedacht, das eine Stromschlaggefahr erkennt und mit den Sicherheitsvorkehrungen vertraut ist, die zur Verhinderung einer möglichen Verletzung getroffen werden müssen. Vor dem Gebrauch des Gerätes lesen Sie bitte das Bedienerhandbuch sorgfältig durch.

Bei bestehender Stromschlaggefahr lassen Sie bitte äußerste Vorsicht walten. An der Testvorrichtung oder den Anschlüssen des Quellenmeßgeräts sind möglicherweise tödliche Spannungen vorhanden. Das American National Standard Institute (ANSI) weist darauf hin, daß eine Stromschlaggefahr dann besteht, wenn die Spannungswerte höher als 30 Volt RMS oder 42.4 Volt Spitzenleistung betragen. **Eine gute Sicherheitsmaßnahme ist die Vermutung, daß in jedem unbekannten Stromkreis vor dem Messen eine gefährliche Spannung besteht.**

Prüfen Sie vor jeder Benutzung alle Verbindungskabel, Prüfkabel und Brücken auf mogliche Abnutzung, Risse oder Brüche.

Berühren Sie zur maximalen Sicherheit nicht die Quellenmeßgerätanschlüsse, Prüfvorrichtungen, Prüfkabel oder Verbindungen zu anderen Geräten, während der zu prüfende Stromkreis mit Strom versorgt wird. Stellen Sie den Strom ab und entladen Sie alle Kondensatoren, bevor Sie Kabel oder Brücken anschließen oder trennen. Halten Sie außerdem den Testanschlußdeckel geschlossen, während das zu prüfende Gerät mit Strom versorgt wird. Der sichere Betrieb erfordert die Benutzung des Deckelschlosses.

Berühren Sie keinen Gegenstand, der eine Stromleitung zur gemeinsamen Seite des zu prüfenden Stromkreises oder der Stromkabelmasse darstellt. Nehmen Sie die Messungen immer mit trockenen Händen vor, während Sie auf einer trockenen, isolierten Oberfläche stehen, die für die zu messende Spannung ausgelegt ist.

Überschreiten Sie nicht die auf der Rückseite des Gerätes vorgegebenen Höchstwerte, die außerdem im Kapitel "Technische Daten und Betrieb" des Bedienerhandbuchs beschrieben sind.

Geräte und Zubehör sollten nicht mit Menschen verbunden sein.

Das ⚡ Zeichen auf einem Modell 237 weist darauf hin, daß an diesen Anschlüssen mehr als 1000V vorhanden sein können.

Ist die ferngesteuerte Erfassung aktiviert, so führt ein offener Erfassungsdraht zu tödlichen Spannungen bei OUTPUT HI und GUARD. Diese Spannung kann Verletzungen oder den Tod herbeiführen und die externen Teile des Stromkreises beschädigen. Achten Sie immer darauf, daß die Erfassungsdrähte richtig angeschlossen sind, bevor Sie die ferngesteuerte Erfassung aktivieren. Ändern Sie die Anschlüsse NIEMALS unter Stromspannung. Achten Sie darauf, daß Sie externe Stromquellen immer entladen und/oder trennen.

Bei Prüfsystemen für mehrfache, miteinander verbundene Geräte stellen Sie entweder alle Modelle 236/237/238 an oder ab.

KONTROLLBEGRIFFE

LOKAL (LOCAL): Bringt Gerät in Lokal-Modus und stellt Frontabdeckungstastenfunktion wieder her.

QUELLENGRUPPE

BETRIEB (OPERATE): Bringt Gerät in Betrieb oder Standby.

QUELLENMESSUNG (SOURCE MEASURE): Bestimmt Quellenspannung und Meßstrom oder Quellenstrom und Meßspannung.

FUNKTION (FUNCTION): Bestimmt Gleichstrom oder Durchlaufbetrieb.

ÜBEREINSTIMMUNG (COMPLIANCE): Prüft die Stufe der Übereinstimmung und den Meßbereich. Sie ändern die gegenwärtige Stufe oder den Bereich, indem Sie den Drehknopf oder das Tastenfeld bedienen und dann ENTER drücken.

MESSGRUPPE

ZEIT (TIME): Prüft Integrationszeitraum. Sie ändern die gegenwärtige Einstellung, indem Sie einen der SELECT Knöpfe betätigen und dann ENTER drücken.

UNTERDRÜCKEN (SUPPRESS): Speichert nächste Umwandlung als Grundwert. Alle folgenden Ablesungen sind dann die Differenz zwischen dem unterdrückten Wert und dem tatsächlichen Signalwert.

FILTER (FILTER): Gibt Status des Meßfilters wieder. Sie ändern den Wert, indem Sie einen der SELECT Knöpfe betätigen und ENTER drücken.

AUTOBEREICH (AUTORANGE): Ermöglicht es dem Gerät, den empfindlichsten Bereich für die vorzunehmende Messung zu wählen.

DURCHLAUFGRUPPE

BESTIMMEN (CREATE): Bestimmt einen Durchlauf und dessen Parameter. Bedienen Sie sich der SELECT Knöpfe, um die Durchlaufart zu ändern und drücken Sie dann ENTER. Benutzen Sie den Drehknopf, um die Durchlaufparameter anzuzeigen und das Tastenfeld, um sie zu ändern.

ÄNDERN (MODIFY): Zeigt Quellen- und Verzögerungswerte der gespeicherten Durchlaufpunkte an. Benutzen Sie den Knopf, um den Durchlaufpunkt zu bestimmen; die SELECT Knöpfe, um die Quellen-oder Verzögerungswerte zu bestimmen, und das Tastenfeld und ENTER, um die Werte zu ändern. Wurde der Quellenwert geändert, so benutzen Sie die SELECT Knöpfe und ENTER, um den Quellenbereich zu ändern.

ANHANG (APPEND): Fügt einem bereits existierenden Durchlauf einen weiteren hinzu. Drücken Sie APPEND, so erscheint der gegenwärtige Durchlauf und dessen Parameter. Benutzen Sie die SELECT Knöpfe, um die Durchlaufart zu ändern und drücken Sie dann ENTER. Benutzen Sie den Drehknopf, um die Durchlaufparameter anzuzeigen und das Tastenfeld, um sie zu ändern.

RÜCKRUF (RECALL): Zeigt Quellenparameter, Meßwerte und verstrichene Zeit für jeden Durchlaufpunkt an. Benutzen Sie den Drehknopf, um den Punkt zu bestimmen und die SELECT Knöpfe zur Wiedergabe der Parameter. Zeigt nur Quellen- und Verzögerungswerte vor dem Durchlauf an.

AUSLÖSERGRUPPE

VORGABEN (SETUP): Prüft gegenwärtigen Triggerstatus. Benutzen Sie den Drehknopf zur Anzeige der Parameter und die SELECT und ENTER Tasten zur Änderung der Parameter.

HANDBETRIEB (MANUAL): Eine leuchtende MANUAL Triggerleuchte zeigt an, daß ein Triggerimpuls nötig ist (Druck auf den MANUAL Knopf, Triggerbefehl über IEEE-488 Vielfachleitung oder externer Eingabetrigger).

DATENEINGABEGRUPPE

Drehknopf: Regelt die Anzeige verschiedener Betriebsparameter, stellt Quellen- und Übereinstimmungswerte ein und regelt — wenn im RECALL-Modus — die Anzeige der Durchlaufdaten.

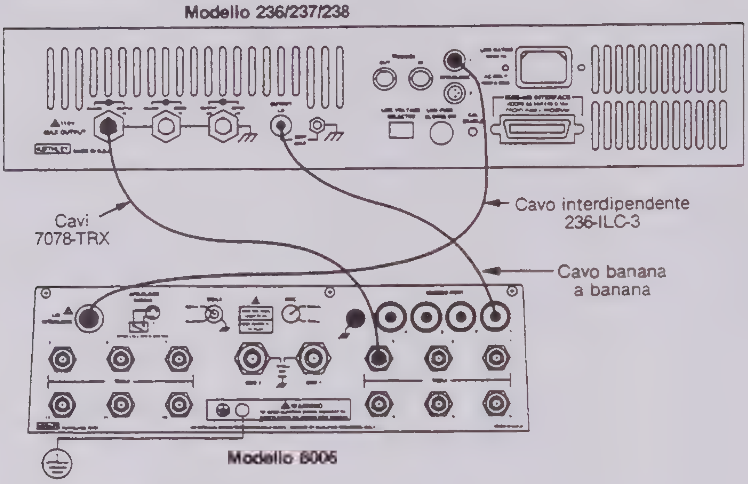
WAHL (SELECT): Mit diesen Knöpfen werden andere Betriebsparameter gewählt und — wenn im RECALL-Modus — die Anzeige der Durchlaufdaten geregelt.

Tastenfeld: Alle Tastenfeldknöpfe (mit Ausnahme von MENÜ/MENU) geben numerische Daten ein oder löschen diese.

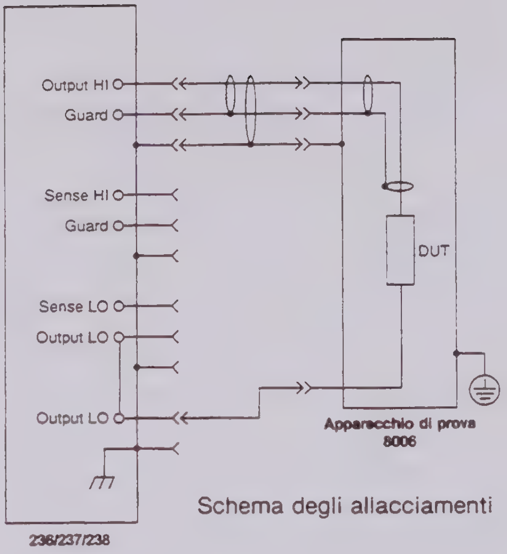
MENÜ (MENU): Dient dazu, folgende Betriebsbedingungen zu prüfen oder zu ändern: Gleichstromverzögerung (0 bis 65 sek), Grundeinstellungsverzögerung (an/aus), Erfassung (lokal/ferngesteuert), Frequenz (50 Hz/60 Hz) und IEEE-488 Adresse (0 bis 30). Dient auch zur Durchführung von Selbstprüfungen.

Allacciamenti tipici

Allacciamenti sensore locale utilizzando apparecchio di prova Modello 8006

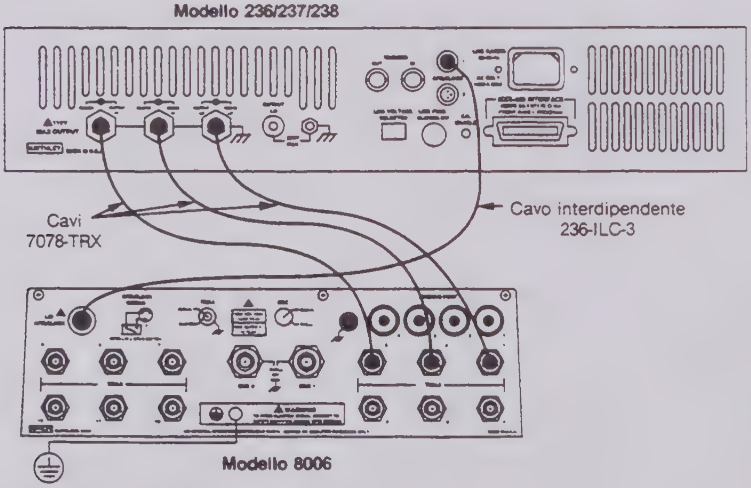

Modello 236/237/238
Cavi 7078-TRX
Cavo interdipendente 236-ILC-3
Cavo banana a banana
Modello 8006

ATTENZIONE: allacciare alla massa di sicurezza.

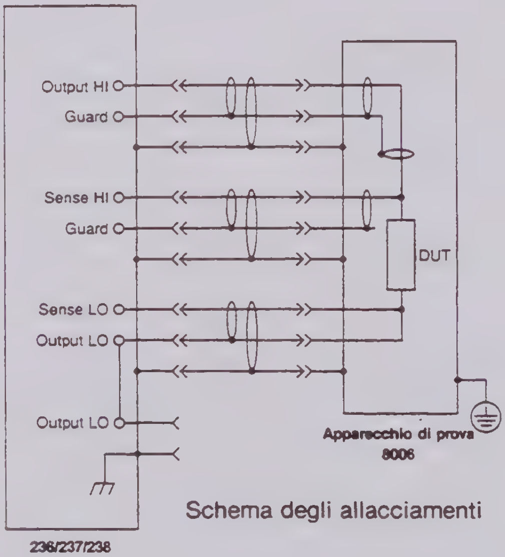

Output HI
Guard
Sense HI
Guard
Sense LO
Output LO
Output LO
DUT
Apparecchio di prova 8006
236/237/238

Schema degli allacciamenti

Allacciamenti sensore a distanza utilizzando apparecchio di prova Modello 8006

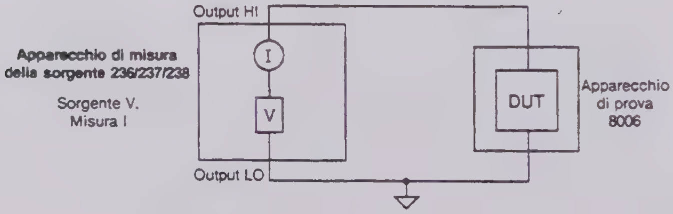

Modello 236/237/238
Cavi 7078-TRX
Cavo interdipendente 236-ILC-3
Modello 8006

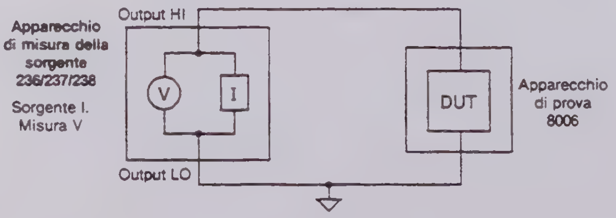
ATTENTIONE: allacciare alla massa di sicurezza.


Output HI
Guard
Sense HI
Guard
DUT
Sense LO
Output LO
Output LO
Apparecchio di prova 8006
236/237/238

Schema degli allacciamenti

Circuiti equivalenti


Output HI
Apparecchio di misura della sorgente 236/237/238
Sorgente V. Misura I
I
V
Output LO
DUT
Apparecchio di prova 8006


Apparecchio di misura della sorgente 236/237/238
Sorgente I. Misura V
Output HI
V
I
Output LO
DUT
Apparecchio di prova 8006

安全に関する注意

モデル236/237/238の供給元測定器を使用する前に、次に示す安全に関する注意をお読みください。

モデル236/237/238の供給元測定器は、怪我の可能性を避けるために必要な安全予防または感電に関して十分な知識をもった有資格者によって使用されるように意図されています。器具を使用する前にオペレーター・マニュアルを必ずお読みください。

感電の危険性がある場合には、特に注意してください。致命的な電圧がテスト取付具や供給元測定器の接続プラグにかかっているかもしれません。アメリカ・ナショナル・スタンダード・インスティチュート（ANSI）は、電圧が30V RMSかピーク電圧が42.4V以上なら、感電の危険性があると述べています。測定する前に未知の回路には、危険な電圧がかかっていると疑ってみることも安全対策の一つです。

毎回使用する前に、かならず接続線、テスト用電線、そしてジャンプ線がすり減ったり、あるいはひびや切断がないかをチェックしてください。

安全性を守るため、テスト中に電気がつながっている間、供給元測定器の接続部、テスト取付具、テスト用電線、または他の接続部には絶対に触れないでください。電線の接続、切断やジャンプをする前に、全ての電気を止めてコンデンサを放電させて下さい。また、テスト中には、装置に送電している時にはテスト取付具のふたを閉めたままにして下さい。

テスト中に回路の共通部に電気路を供給するものや電気アース線に触れないでください。また、測定電圧に耐える乾燥状態の絶縁体は、常にかわいた手で測定してください。

後ろにあるパネル、仕様書、そしてインストラクション・マニュアルのオペレーション・セクションに記されているように、器具の最大シグナルを越えないでください。

器具や付属品を人に接続しないでください。

モデル237にある ⚡ のシンボルは、端子に1000ボルト以上の電圧がかかっている可能性があるということを提示しています。

リモートセンサーを使うと、オープンセンスの電線は、アウトプット HI とガードに致命的な電圧を引き起こします。この電圧は、怪我や死亡、そして外部の回路を破損する原因になります。リモートセンスを可能にする前に、センスの電線が正しく接続されているかを常に確認してください。電気が流れている状態では、決して接続をかえないでください。常に放電をして、外部の電源を止めてください。

並列ユニット・インターロックのテスト・システムのためには、すべてのモデル236/237/238の電気をONか、あるいはすべてをOFFにしておいて下さい。

コントロールに関する要約

ローカル *(LOCAL)*: ユニットをローカルにして、前部のパネルのキー・オペレーションをもとに戻します。

供給元（ソース）グループ

オペレート *(OPERATE)*: ユニットをオペレート、あるいはスタンバイにします。

供給元測定 *(SOURCE MEASURE)*: ソース電圧と測定電流、またはソース電流と測定電圧のどちらかを選択します。

ファンクション *(FUNCTION)*: 直流またはスウィープを選択します。

コンプリアンス *(COMPLIANCE)*: コンプリアンスのレベルをチェックして、レンジを測定します。現在のレベルとレンジを回転式のつまみかキーパッドを使って変えて、エンターを押してください。

測定グループ

タイム *(TIME)*: インテグレーションの期間をチェックします。現在の選択をセレクトのボタンを押してかえ、エンターを押してください。

サプレス *(SUPPRESS)*: ベースラインとして次の転換を記憶します。その後の測定値は、削除した値と実際のシグナルレベルと異なります。

フィルター *(FILTER)*: 測定フィルターの状態を表示します。セレクト・ボタンを押して、フィルターの量を変えて、エンターを押します。

オートレンジ *(AUTORANGE)*: ユニットを測定する最も感度の高いレンジにすることができます。

スウィープ・グループ

クリエート *(CREATE)*: スウィープを選択して、そのパラメーターを定義します。スウィープのタイプを変えるためにセレクト・ボタンを使って、エンターを押してください。スウィープ・パラメーターを表示するために回転つまみを使用し、そしてキーパッドを使ってください。

モディファイ *(MODIFY)*: ソースと記憶されているスウィープポイントの遅延値を表示します。スウィープポイントの選択はつまみを使用します。ソースや遅延値の選択には、セレクト・ボタンを押して下さい。また値の変更はキーパッドとエンターを押して下さい。そしてソース値の変更は、セレクト・ボタンとエンターを使ってください。

アペンド *(APPEND)*: スウィープに既に存在するスウィープを加えます。アペンドを押すと現在のスウィープとそのパラメーターを表示します。スウィープのタイプを変えるにはセレクト・ボタンを使って、そしてエンターを押します。スウィープのパラメーターを表示するには回転つまみとキーパッドを使ってください。

リコール *(RECALL)*: ソースパラメーター、測定値、そして各々のウィープポイントの経過時間を表示します。ポイントの選択には回転つまみを、パラメーターの表示にはセレクト・ボタンを使ってください。リコールはスウィープが作動する前にソースと遅延値のみを表示します。

始動（トリガー）グループ

セットアップ *(SETUP)*: 現在のトリガー状態をチェックします。パラメーターの表示には回転つまみを、またパラメーターの変更にはセレクトキーとエンターキーを使ってください。

マニュアル *(MANUAL)*: マニュアルのトリガーライトの点滅は、トリガーの刺激が必要であることを示しています。（マニュアルボタンを押して、IEEE-488バスか外部インプットトリガーにトリガーコマンド）

データー入力グループ

ロータリーノブ *(Rotary Knob)*: いろいろなオペレーション・パラメーターの表示をコントロールし、ソースとコンプリアス値を調節します。リコール状態では、スウィープ・データーの表示をコントロールします。

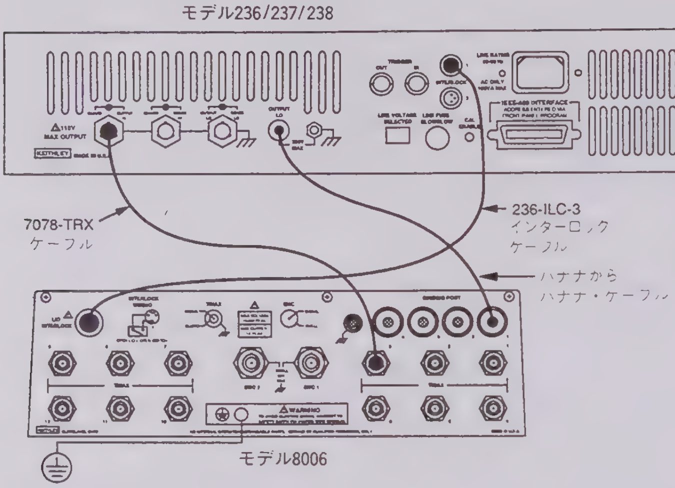
セレクト *(SELECT)*: これらのボタンは、代わりのオペレーション・パラメーターを選択し、リコールの時にはスウィープデーターの表示をコントロールします。

キーパッド *(Keypad)*: すべてのキーパッドのボタン（メニューを除く）は、数字データーの入力または削除を行います。

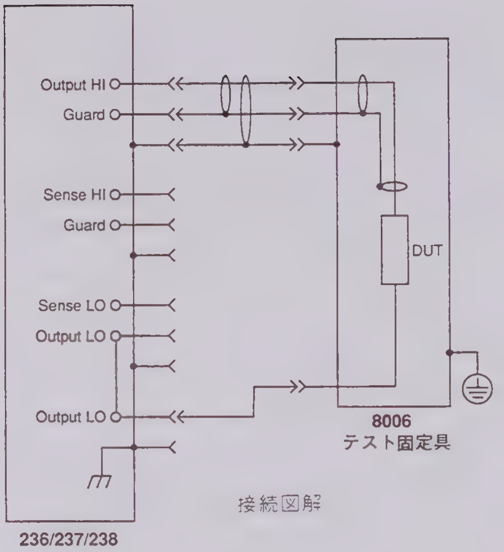
メニュー *(MENU)*: 次のオペレーション状態をチェックしたり、変更するのに使用されます。DCの遅延（0から65秒）、デフォルトの遅延（オンかオフ）、センス（ローカル/リモート）、ライン周波数（50Hzか60Hz）、IEEE-488アドレス（0から30）。また自動テストにも使用されます。

典型的な接続

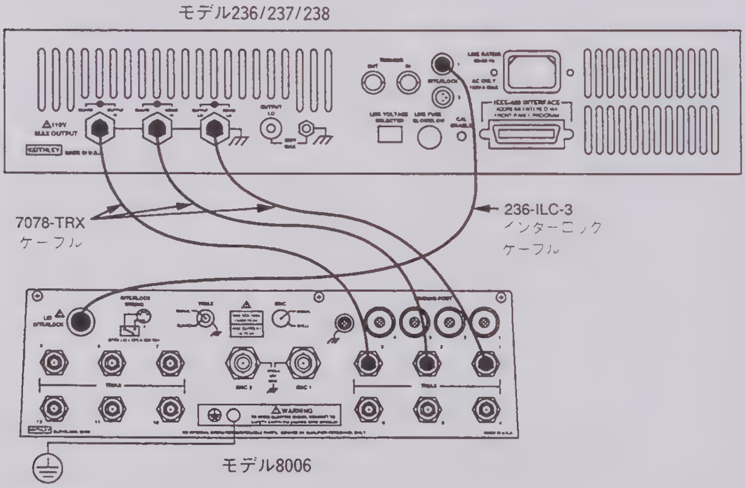
モデル8006 テスト固定具を使ってローカルセンスの接続


モデル236/237/238
7078-TRX
ケーブル
236-ILC-3
インターロック
ケーブル
バナナから
バナナ・ケーブル
モデル8006

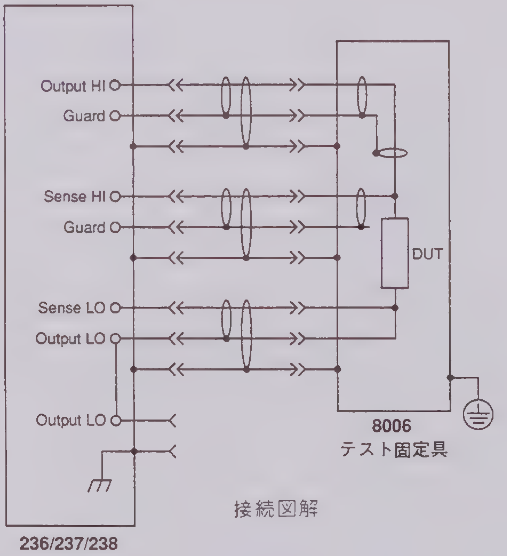
注意：安全にアースして下さい。


Output HI
Guard
Sense HI
Guard
Sense LO
Output LO
Output LO
DUT
8006
テスト固定具
接続図解
236/237/238

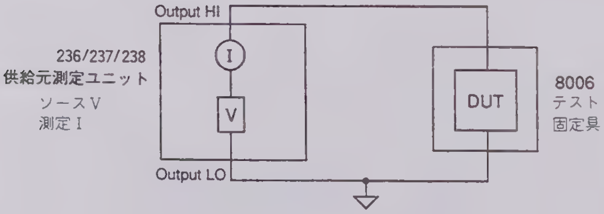
モデル8006 テスト固定具を使ってリモートセンスの接続

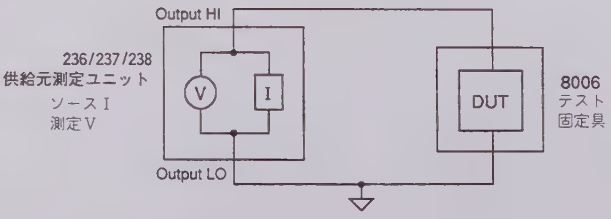

モデル236/237/238
7078-TRX
ケーブル
236-ILC-3
インターロック
ケーブル
モデル8006

注意：安全にアースして下さい。


Output HI
Guard
Sense HI
Guard
DUT
Sense LO
Output LO
Output LO
8006
テスト固定具
接続図解
236/237/238

等価回路


Output HI
236/237/238
供給元測定ユニット
ソースV
測定 I
I
V
DUT
8006
テスト
固定具
Output LO


Output HI
236/237/238
供給元測定ユニット
ソース I
測定 V
V
I
DUT
8006
テスト
固定具
Output LO

MEDIDAS DE SEGURIDAD

Es necesario tomar las medidas de seguridad antes de usar los aparatos medidores de fuente modelos 236/237/238.

El medidor modelo 236/237/238 está diseñado para ser usado por personal experimentado capaz de reconocer los peligros de los electrochoques y conocedor de las medidas de seguridad requeridas para evitar la posibilidad de sufrir lesiones. Leer el manual del operador cuidadosamente antes de usar este instrumento.

Tener sumo cuidado cuando exista peligro de electrochoque. Podría haber voltaje mortal presente en los enchufes conectores del probador o medidor de fuente. El Instituto de Normalizaciones Nacional Norteamericano (ANSI) establece que existe peligro de electrochoque cuando los niveles de voltaje son superiores a 30 V RMS o de cresta de 42.4V. **Una buena medida de seguridad es anticipar la presencia de voltajes peligrosos en cualquier circuito desconocido antes de tomar mediciones.**

Inspeccionar los cables de conexión, conductores de prueba y cables puente en busca de posible desgaste, grietas o roturas antes de cada uso.

Para máxima seguridad, no tocar los conectores del medidor, probador, cables de prueba o cualquier otro conector de instrumento mientras se aplica corriente eléctrica al circuito que se está probando. Cortar toda la corriente eléctrica y descargar los capacitores antes de conectar o desconectar cables o cables puente. También, mantener cerrada la tapa del probador mientras se aplica corriente al dispositivo que se está probando. La operación segura requiere el uso de un enclavamiento de la tapa.

No tocar ningún objeto que pudiera proporcionar un paso de corriente al lado común del circuito sometido a prueba o tierra del cable de energía eléctrica. Siempre tomar las mediciones con las manos secas de pie sobre una superficie seca y aislada capaz de resistir el voltaje que se está midiendo.

No exceder los niveles máximos de señal del instrumento, como se indica en el panel trasero y como se define en las especificaciones y sección de operación del manual de instrucciones.

No se deben conectar los instrumentos y accesorios a seres humanos.

El símbolo ⚡ que aparece en el modelo 237 indica que en los terminales puede haber presente 1000V o más.

Con el detector remoto habilitado, un conductor de detección abierto dará por resultado la aparición de voltajes mortales en la conexión de SALIDA ALTA y de GUARDA (OUTPUT HI y GUARD). Este voltaje puede causar lesiones e incluso la muerte, y dañar los circuitos exteriores. Siempre asegurar que los conductores de detección estén bien conectados antes de habilitar el detector remoto. NUNCA cambiar las conexiones estando la energía eléctrica aplicada. Siempre asegurar de descargar y/o desconectar la fuentes de suministro de energía externas.

Para los sistemas de prueba interconectados de medidores múltiples, se deberá mantener ya sea todos los modelos 236/237/238 energizados, o todos desenergizados.

RESUMEN DE LOS CONTROLES

LOCAL (LOCAL): Pone el instrumento en local y restablece las operaciones del panel frontal.

GRUPO DE LA FUENTE

OPERAR (OPERATE): Pone la unidad en estado de funcionamiento o de reserva.

MEDIDA FUENTE (SOURCE MEASURE): Selecciona tensión primaria o de fuente y corriente de medida, o corriente de fuente y tensión de medida.

FUNCION (FUNCTION): Selecciona operación cc o de barrido.

DOCILIDAD (COMPLIANCE): Verifica el nivel de docilidad y el margen de medida. Cambiar el nivel y margen en curso con la ayuda de la perilla o teclado y luego pulsar ENTER.

GRUPO DE MEDICION

TIEMPO (TIME): Verifica el período de integración. Cambiar la selección en curso pulsando los botones SELECT (SELECCIONAR) y luego ENTER (ENTRAR).

SUPRIMIR (SUPPRESS): Guarda la conversión siguiente como una medición de línea de base. Las lecturas subsiguientes serán la diferencia entre el valor suprimido y el nivel real de la señal.

FILTRO (FILTER): Indica el estado del filtro de medición. Cambiar la cantidad de filtración pulsando los botones SELECT y luego ENTER.

AUTOGAMA (AUTORANGE): Permite al aparato pasar a la gama o margen más sensible para tomar una medida.

GRUPO DE BARRIDO

CREAR (CREATE): Selecciona un barrido y define sus parámetros. Usar los botones SELECT para cambiar el tipo de barrido y en seguida pulsar ENTER. Usar la perilla giratoria para visualizar los parámetros de barrido y el teclado para cambiarlos.

MODIFICAR (MODIFY): Visualiza los valores de retardo y de fuente de los puntos de barrido registrados en la memoria. Usar la perilla para elegir el punto de barrido, los botones SELECT para elegir el valor de fuente o de retardo, el teclado y la tecla ENTER para cambiar los valores. Si el valor de fuente cambió, usar los botones SELECT y ENTER para cambiar el margen de la fuente de energía.

AGREGAR (APPEND): Añade un barrido a un barrido ya existente. Al pulsar APPEND se visualiza el barrido en curso y sus parámetros. Usar los botones SELECT para cambiar el tipo de barrido y en seguida pulsar ENTER. Usar la perilla giratoria para visualizar los parámetros de barrido y el teclado para cambiarlos.

LLAMAR (RECALL): Visualiza los parámetros de la fuente, los valores de medición y el tiempo transcurrido para cada punto de barrido. Usar la perilla giratoria para elegir el punto y los botones SELECT para visualizar los parámetros. Visualiza los valores de fuente y de retardo solamente antes de ejecutarse el barrido.

GRUPO DE DISPARADORES

PREPARACION (SETUP): Verifica la condición o estado actual del disparador. Usar la perilla giratoria para visualizar los parámetros, las teclas SELECT y ENTER para cambiar los parámetros.

MANUAL (MANUAL): La luz destellante del disparador MANUAL indica que se requiere un impulso de disparo (pulsación del botón MANUAL, comando de disparo sobre la barra colectora o bus IEEE-488, o un disparador de entrada exterior).

GRUPO DE ENTRADA DE DATOS

Perilla giratoria: Controla la visualización de los distintos parámetros de operación, ajusta los valores de fuente y de docilidad, y cuando está en modo RECALL, controla la visualización de los datos de barrido.

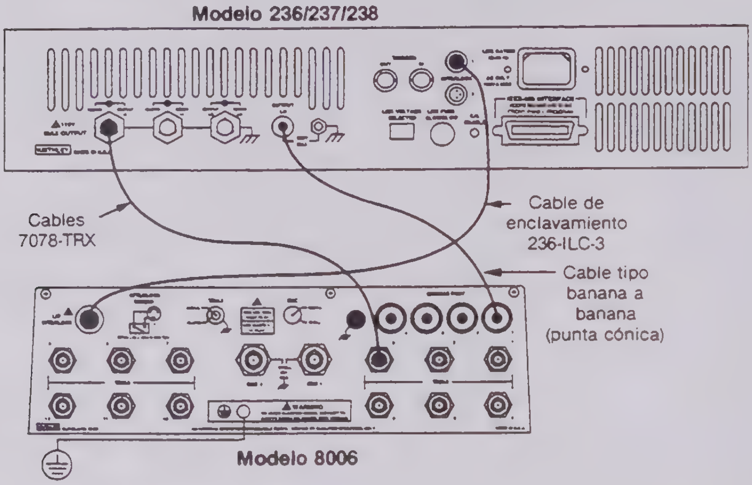
SELECCIONAR (SELECT): Estos botones seleccionan los parámetros operacionales alternativos y, cuando está en modo RECALL, controlan la visualización de los datos de barrido.

Teclado: Todos los botones del teclado (excepto MENU) sirven para entrar (registrar) o anular datos numéricos.

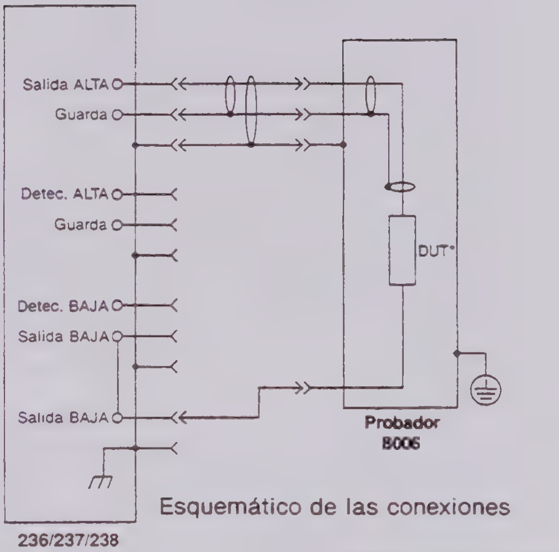
MENU (MENU): Se usa para verificar o cambiar las siguientes condiciones de operación: retardo cc (0 a 65 segundos), retardo predeterminado por defecto (activado/desactivado), detección (local/remota), frecuencia de línea (50 Hz/60 Hz), y dirección IEEE-488 (0 a 30). También se usa para ejecutar autopruebas.

Conexiones típicas

Conexiones de detección local con el probador modelo 8006


Modelo 236/237/238
Cables 7078-TRX
Cable de enclavamiento 236-ILC-3
Cable tipo banana a banana (punta cónica)
Modelo 8006

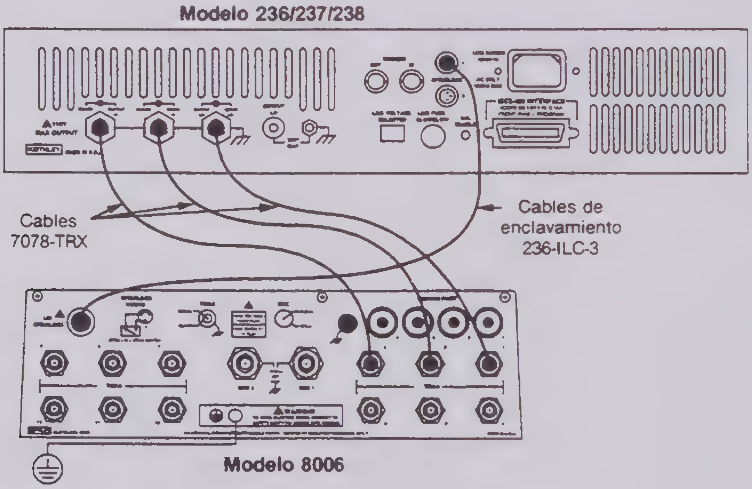
ADVERTENCIA: Conectar a una puesta a tierra segura.


Salida ALTA
Guarda
Detec. ALTA
Guarda
Detec. BAJA
Salida BAJA
Salida BAJA
DUT*
Probador 8006
236/237/238

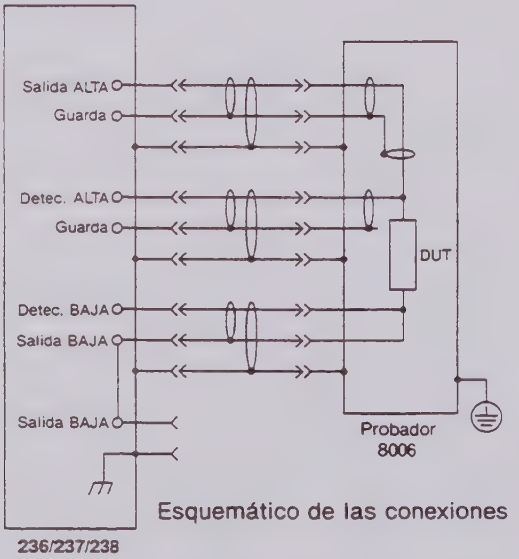
Esquemático de las conexiones

*DUT = Aparato en período de pruebas

Conexiones de detección remota con probador modelo 8006

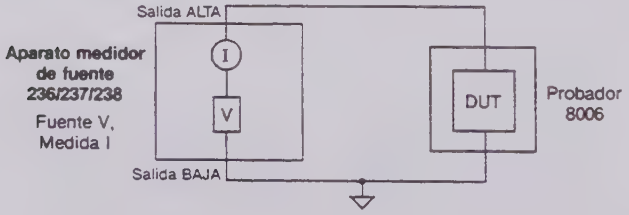

Modelo 236/237/238
Cables 7078-TRX
Cables de enclavamiento 236-ILC-3
Modelo 8006

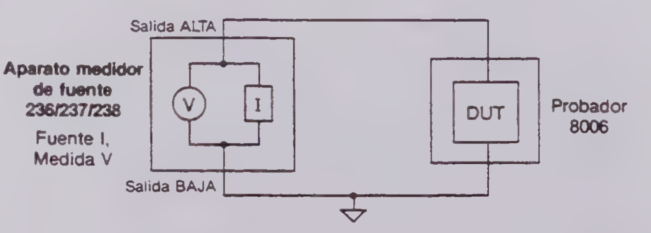
ADVERTENCIA: Conectar a una puesta a tierra segura.


Salida ALTA
Guarda
Detec. ALTA
Guarda
Detec. BAJA
Salida BAJA
Salida BAJA
DUT
Probador 8006
236/237/238

Esquemático de las conexiones

Circuitos equivalentes


Salida ALTA
Aparato medidor de fuente 236/237/238
Fuente V, Medida I
I
V
Salida BAJA
DUT
Probador 8006

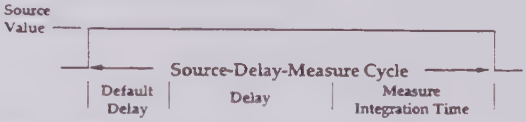

Salida ALTA
Aparato medidor de fuente 236/237/238
Fuente I, Medida V
V
I
Salida BAJA
DUT
Probador 8006

Models 236 and 237 Source Measure Units Specifications

SOURCE-MEASURE UNIT: Sources voltage while measuring current, or sources current while measuring voltage.

FUNCTION: Can be used as DC source or meter, sweep source, or full source-measure unit.

SOURCE-DELAY-MEASURE CYCLE:



Default Delay: Fixed delay for instrument settling.

User Delay: Additional delay for device under test or system capacitance.

MEASURE:

Integration Time:

Fast	416	µsec.	4 digit resolution
Medium	4	msec.	5 digit resolution
Line Cycle	16.67	msec. (60 Hz)	5 digit resolution
	20.00	msec. (50 Hz)	

Elapsed Time: Measures and stores time from sweep trigger to measurement complete for each step of sweep.

RANGING:

Source: Auto-ranging through keypad entry; fixed range selection using rotary dial and SELECT keys (DC function). Fully programmable in SWEEP function.

Measure: Auto or fixed range. Fixed range selection made by choice of COMPLIANCE value.

FILTER: Takes n measurements, calculates and outputs average (n = 2, 4, 8, 16, or 32, selectable).

SUPPRESS: Subtracts displayed measurement from subsequent readings.

MENU: DC Measurement Delay, Default Delay On/Off, Local/Remote Sense, 50/60Hz, IEEE Address, Self Tests.

DATA ENTRY: Numeric keypad or detented rotary dial.

TRIGGER:

Input and Output: Set for any phase of SOURCE-DELAY-MEASURE sequence or trigger output at end of sweep.

Origin: Internal, External (including front panel MANUAL TRIGGER button), IEEE-488 bus (TALK, GET, "X").

MEMORY: Stores one full sweep (up to 1000 points) of source, delay, and measure values, elapsed times, and sweep parameters. Lithium battery backup.

INTERLOCK: Use with test fixture or external switch. Normally closed; open puts instrument in standby.

Specifications subject to change without notice.

VOLTAGE

SOURCE V			MEASURE V		
RANGE (Max. Value)	STEP SIZE	ACCURACY (1 Year, 18°–28°C)	RESOLUTION 4-Digit	RESOLUTION 5-Digit	ACCURACY[1] (1 Year, 18°–28°C)
±1.1000V[2]	100 µV	±(0.033%+650 µV + $[I_O/I_{FS}] \times 450\mu V$)	100 µV	10 µV	±(0.028% + 300µV + $[I_O/I_{FS}] \times 450\mu V$)
±11.000V	1 mV	±(0.033%+ 2.4mV)	1 mV	100 µV	±(0.025%+ 1mV)
±110.00V	10 mV	±(0.033%+ 24mV)	10 mV	1 mV	±(0.025%+ 10mV)
±1100.0V[3]	100 mV	±(0.04 %+240mV)	100 mV	10 mV	±(0.035%+100mV)

I_O = Output current

I_{FS} = Full scale on selected current range

---

[1] Specifications apply for 5-digit resolution. For 4-digit resolution add 100ppm of range.

[2] Assumes remote sense for I > 100µA.

[3] 1100V range available on Model 237 only.

COMPLIANCE: Bipolar current limit set with single value.

Maximum: ±100mA (except ±10mA on 1100V range in Model 237).

Minimum: ±0.1% of range, except 0.5% of 1.1V range.

Accuracy, Step Size: Same as current source.

NOISE (p-p):

Range	0.1–10Hz
110V–1100V	< 3ppm of range
11 V	< 3ppm of range
1.1 V	<10ppm of range

WIDEBAND NOISE: 0.1 to 20MHz, 8mV p-p typical.

OVERSHOOT: <0.01% (110V step, 10mA range).

SETTLING TIME: <500µsec. to 0.01% (110V step, 10mA range).

NMRR: >60dB at 50 or 60Hz (LINE CYCLE integration time selected).

CMRR: >120dB at DC, 50 or 60Hz (LINE CYCLE integration time selected).

INPUT IMPEDANCE (as a voltmeter): >$10^{14}\Omega$ paralleled by <20pF.

CURRENT

SOURCE I			MEASURE I		
RANGE (Max. Value)	STEP SIZE	ACCURACY (1 Year, 18°–28°C)	RESOLUTION 4-Digit	RESOLUTION 5-Digit	ACCURACY[1] (1 Year, 18°–28°C)
±1.0000 nA	100 fA	±(0.3 %+450 fA)	100 fA	10 fA	±(0.3 %+100 fA)[2]
±10.000 nA	1 pA	±(0.3 %+ 2 pA)	1 pA	100 fA	±(0.3 %+ 1 pA)
±100.00 nA	10 pA	±(0.21%+ 20 pA)	10 pA	1 pA	±(0.21 %+ 6 pA)
±1.0000 µA	100 pA	±(0.05%+200 pA)	100 pA	10 pA	±(0.04 %+ 60 pA)
±10.000 µA	1 nA	±(0.05%+ 2 nA)	1 nA	100 pA	±(0.035%+700 pA)
±100.00 µA	10 nA	±(0.05%+ 20 nA)	10 nA	1 nA	±(0.035%+ 6 nA)
±1.0000 mA	100 nA	±(0.05%+200 nA)	100 nA	10 nA	±(0.035%+ 60 nA)
±10.000 mA	1 µA	±(0.05%+ 2 µA)	1 µA	100 nA	±(0.038%+600 nA)
±100.00 mA	10 µA	±(0.1 %+ 20 µA)	10 µA	1 µA	±(0.1 %+ 6 µA)

---

[1] Specifications apply for 5-digit resolution. For 4-digit resolution, all offset terms are 200ppm of range.

[2] Offset specification applies for 23°C ± 1°C with suppression. Temperature coefficient 50fA/°C.

COMPLIANCE: Bipolar voltage limit set with single value.

Maximum: ±1100V (except ±110V on 100mA range in Model 237).

Minimum: ±0.1% of selected current range.

Accuracy, Step Size: Same as voltage source.

NOISE (p-p of range): 0.1–10Hz: <3ppm (<20ppm on 1nA and 10nA ranges).

OVERSHOOT: <0.01% typical (10mA step, R_L = 10kΩ).

SETTLING TIME: <500µsec. to 0.01% (10mA step, R_L = 10kΩ).

OUTPUT R, C: >$10^{14}\Omega$ paralleled by <20pF (on 1nA range).

VOLTAGE BURDEN (as an ammeter): <1mV.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and setups are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, and Terminator.

IEEE-488 address is set from front panel menu.

EXECUTION SPEED

MINIMUM SOURCE-DELAY-MEASURE CYCLE TIME: 1msec.

RESPONSE TO IEEE-488 COMMAND (as a source): 25msec.

MEASUREMENT RATE: 1msec. per point into internal buffer.

CONTINUOUS MEASUREMENT SPEED (source DC value over IEEE-488 bus): 110 readings per second.

TRIGGER LATENCY TIME: <2msec.

GENERAL

LOAD CAPACITANCE: Stable into 20,000pF typical.

REMOTE SENSE: Corrects for up to 2V drop in each output lead. Maximum 1kΩ per sense lead for rated accuracy. Residual output resistance (as a voltage source) is 0.5Ω.

GUARD: **Output Resistance:** ≤12kΩ.
Maximum Output Current: ±2mA.
Offset Relative to Output HI: ±2mV max.

ISOLATION (Output LO to chassis): Typically $>10^{10}\Omega$ in parallel with 500pF.

MAXIMUM COMMON MODE VOLTAGE: 200V.

CONNECTORS: **Outputs:** 3-lug triax.
Trigger Input/Output: BNC.
Interlock: 3-pin miniature DIN.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C):
±(0.1 × applicable accuracy specification)/°C.

ENVIRONMENT:

Operating: 0°–50°C, 70% relative humidity up to 35°C. Linearly derate 3% RH/°C, 35°–50°C.

Storage: –25° to 65°C.

WARM-UP: One hour to rated accuracy.

COOLING: Internal fan forced air cooling.

POWER: 105–125 or 210–250V AC (external switch selectable), 90–110V and 180–220V version available. 100VA max.

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3.5 in. × 17.125 in. × 17.625 in.). Net weight 9kg (19.75 lbs.).

ACCESSORIES SUPPLIED:
Model 7078-TRX-10: Triax to Triax Cable, 3m (10 ft.) (2 supplied)
Model 236-ILC-3: Interlock Cable

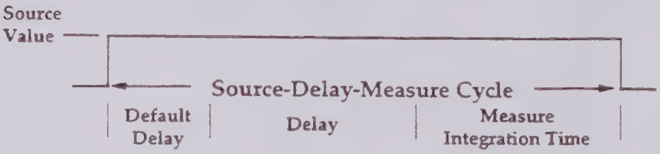
ACCESSORIES AVAILABLE:
Model 8000-10: Equipment Rack for 3 SMUs (10 in.)
Model 8000-14: Equipment Rack for 4 SMUs (14 in.)

Model 238 Source Measure Unit Specifications

SOURCE-MEASURE UNIT: Sources voltage while measuring current, or sources current while measuring voltage.

FUNCTION: Can be used as DC source or meter, sweep source, or full source-measure unit.

SOURCE-DELAY-MEASURE CYCLE:



Default Delay: Fixed delay for instrument settling.

User Delay: Additional delay for device under test or system capacitance.

MEASURE:

Integration Time:

Fast	416 µsec.	4-digit resolution
Medium	4 msec.	5-digit resolution
Line Cycle	16.67 msec. (60 Hz) 20.00 msec. (50 Hz)	5-digit resolution

Elapsed Time: Measures and stores time from sweep trigger to measurement complete for each step of sweep.

RANGING:

Source: Auto-ranging through keypad entry; fixed range selection using rotary dial and SELECT keys (DC function). Fully programmable in SWEEP function.

Measure: Auto or fixed range. Fixed range selection made by choice of COMPLIANCE value.

FILTER: Takes n measurements, calculates and outputs average (n = 2, 4, 8, 16, or 32, selectable).

SUPPRESS: Subtracts displayed measurement from subsequent readings.

MENU: DC Measurement Delay, Default Delay On/Off, Local/Remote Sense, 50/60Hz, IEEE Address, Self Tests.

DATA ENTRY: Numeric keypad or detented rotary dial.

TRIGGER:

Input and Output: Set for any phase of SOURCE-DELAY-MEASURE sequence or trigger output at end of sweep.

Origin: Internal, External (including front panel MANUAL TRIGGER button), IEEE-488 bus (TALK, GET, "X").

MEMORY: Stores one full sweep (up to 1000 points) of source, delay, and measure values, elapsed times, and sweep parameters. Lithium battery backup.

INTERLOCK: Use with test fixture or external switch. Normally closed; open puts instrument in standby.

Specifications subject to change without notice.

VOLTAGE

SOURCE V			MEASURE V		
RANGE (Max. Value)	STEP SIZE	ACCURACY (1 Year, 18°–28°C)	RESOLUTION 4-Digit	RESOLUTION 5-Digit	ACCURACY[1] (1 Year, 18°–28°C)
±1.5000V	100 µV	±(0.033% + 800µV + $[I_O/I_{FS}] \times 600\mu V$)[2]	100 µV	10 µV	±(0.028% + 450µV + $[I_O/I_{FS}] \times 600\mu V$)[2]
±15.000V	1 mV	±(0.033% + 2.7mV)	1 mV	100 µV	±(0.025% + 1.3mV)
±110.00V	10 mV	±(0.033% + 24mV)	10 mV	1 mV	±(0.025% + 10mV)

I_O = Output current
I_{FS} = Full scale on selected current range

[1] Specifications apply for 5-digit resolution. For 4-digit resolution add 100ppm of range. Assumes remote sense for I > 100µA.

[2] On the 1A range use $[I_O/I_{FS}] \times 250\mu V$.

COMPLIANCE: Bipolar current limit set with single value.

Maximum: ±1A (±100mA on the 110V range).

Minimum: ±1% of selected voltage range.

Accuracy, Step Size: Same as current source.

NOISE (p-p typical):

Range	0.1–10Hz
110 V	< 3ppm of range
15 V	< 3ppm of range
1.5 V	<10ppm of range

WIDEBAND NOISE: 0.1 to 20MHz, 8mV p-p typical.

OVERSHOOT: <0.01% (110V step, 10mA range).

SETTLING TIME: <500µsec. to 0.01% (110V step, 10mA range).

NMRR: >60dB at 50 or 60Hz (LINE CYCLE integration time selected).

CMRR: >120dB at DC, 50 or 60Hz (LINE CYCLE integration time selected).

INPUT IMPEDANCE (as a voltmeter): $>10^{14}\Omega$ paralleled by <20pF.

CURRENT

SOURCE I			MEASURE I		
RANGE (Max. Value)	STEP SIZE	ACCURACY (1 Year, 18°–28°C)	RESOLUTION 4-Digit	RESOLUTION 5-Digit	ACCURACY[1,2] (1 Year, 18°–28°C)
±1.0000 nA	100 fA	±(0.3 % + 450 fA)	100 fA	10 fA	±(0.3 % + 100 fA)[2]
±10.000 nA	1 pA	±(0.3 % + 2 pA)	1 pA	100 fA	±(0.3 % + 1 pA)
±100.00 nA	10 pA	±(0.21% + 20 pA)	10 pA	1 pA	±(0.21 % + 6 pA)
±1.0000 µA	100 pA	±(0.05% + 200 pA)	100 pA	10 pA	±(0.04 % + 60 pA)
±10.000 µA	1 nA	±(0.05% + 2 nA)	1 nA	100 pA	±(0.035% + 700 pA)
±100.00 µA	10 nA	±(0.05% + 20 nA)	10 nA	1 nA	±(0.035% + 6 nA)
±1.0000 mA	100 nA	±(0.05% + 200 nA)	100 nA	10 nA	±(0.035% + 60 nA)
±10.000 mA	1 µA	±(0.05% + 2 µA)	1 µA	100 nA	±(0.038% + 600 nA)
±100.00 mA	10 µA	±(0.1 % + 20 µA)	10 µA	1 µA	±(0.1 % + 6 µA)
±1.0000 A	100 µA	±(0.12% + 700 µA)	100 µA	10 µA	±(0.12 % + 300 µA)

[1] Specifications apply for 5-digit resolution. For 4-digit resolution, all offset terms are 200ppm of range.

[2] Offset specification applies for 23°C ± 1°C with suppression. Temperature coefficient 50fA/°C.

COMPLIANCE: Bipolar voltage limit set with single value.

Maximum: ±110V (±15V on the 1A range).

Minimum: ±1% of selected current range.

Accuracy, Step Size: Same as voltage source.

NOISE (p-p of range): 0.1–10Hz: <3ppm (<20ppm on 1nA, 10nA and 1A ranges).

OVERSHOOT: <0.01% typical (10mA step, R_L = 10kΩ).

SETTLING TIME: <500µsec. to 0.01% (10mA step, R_L = 10kΩ).

OUTPUT R, C: $>10^{14}\Omega$ paralleled by <20pF (on 1nA range).

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and setups are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, and Terminator.

IEEE-488 address is set from front panel menu.

EXECUTION SPEED

MINIMUM SOURCE-DELAY-MEASURE CYCLE TIME: 1msec.

RESPONSE TO IEEE-488 COMMAND (as a source): 25msec.

MEASUREMENT RATE: 1msec. per point into internal buffer.

CONTINUOUS MEASUREMENT SPEED (source DC value over IEEE-488 bus): 110 readings per second.

TRIGGER LATENCY TIME: <2msec.

GENERAL

LOAD CAPACITANCE: Stable into 20,000pF typical.

REMOTE SENSE: Corrects for up to 2V drop in each output lead. Maximum 1kΩ per sense lead for rated accuracy. Residual output resistance (as a voltage source) is 0.5Ω.

GUARD: **Output Resistance:** ≤12kΩ.
Maximum Output Current: ±2mA.
Open Circuit Offset Relative to Output HI: ±2mV max.

ISOLATION (Output LO to chassis): Typically $>10^{10}\Omega$ in parallel with 650pF.

MAXIMUM COMMON MODE VOLTAGE: 200V peak.

CONNECTORS: **Outputs:** 3-lug triax.
Trigger Input/Output: BNC.
Interlock: 3-pin miniature DIN.

TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

ENVIRONMENT:
Operating: 0°–50°C, 70% relative humidity up to 35°C. Linearly derate 3% RH/°C, 35°–50°C.
Storage: –25° to 65°C.

WARM-UP: One hour to rated accuracy.

COOLING: Internal fan forced air cooling.

POWER: 105–125 or 210–250V AC (external switch selectable), 90– 110V and 180–220V version available. 120VA max.

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3½ in. × 17⅛ in. × 17⅝ in.). Net weight 9kg (19.75 lbs.).

ACCESSORIES SUPPLIED:

Model 7078-TRX-10:	Triax to Triax Cable, 3m (10 ft.) (2 supplied)
Model 236-ILC-3:	Interlock Cable

ACCESSORIES AVAILABLE:

Model 8000-10:	Equipment Rack for 3 SMUs (10 in.)
Model 8000-14:	Equipment Rack for 4 SMUs (14 in.)

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SECTION 1
Getting Started

1.1 INTRODUCTION

SECTION 1
Getting Started

1.1 INTRODUCTION

This section contains introductory information on operating your Source Measure Unit and is intended to help you get it up and running as quickly as possible. The information is divided (tabbed) into three parts:

Source-Measure Concepts

The information in this part will provide a basic understanding of the Source Measure Unit.

1.2 Operation Overview: An overview will cover basic operation, which includes its source and measure capabilities, the source-delay-measure (SDM) cycle, operating functions (dc and sweep), and expands on its sweep capabilities.

1.3 Basic Circuit Configurations: Simplified circuits, along with brief explanations, are provided to show the Source Measure Unit configured as a voltage source and as a current source.

1.4 Guard and Remote Sensing: Provides basic information on its driven guard and remote sensing capabilities.

1.5 Operating Boundaries: Covers the operating boundaries (limits) of the Source Measure Unit and explains the effect of the load on its operating point.

Front and Rear Panel Familiarization

1.6 Front Panel Familiarization: Briefly describes the display and each front panel control.

1.7 Rear Panel Familiarization: Outlines each aspect of the rear panel including connectors and switches.

Basic Source-Measure Techniques

1.8 Power-Up: Summarizes line voltage and frequency settings, and power connection requirements.

1.9 Connections: Explains how to connect the Source Measure Unit to the Model 8006 test fixture and how to make test connections to DUT.

1.10 Source-Measure Examples: Provides test examples to demonstrate dc operation and sweep operation. HP BASIC 4.0 programs are also provided to demonstrate the tests over the IEEE-488 bus.

Source-Measure Concepts

1.2 OPERATION OVERVIEW
1.3 BASIC CIRCUIT CONFIGURATIONS
1.4 GUARD AND REMOTE SENSING
1.5 OPERATING BOUNDARIES

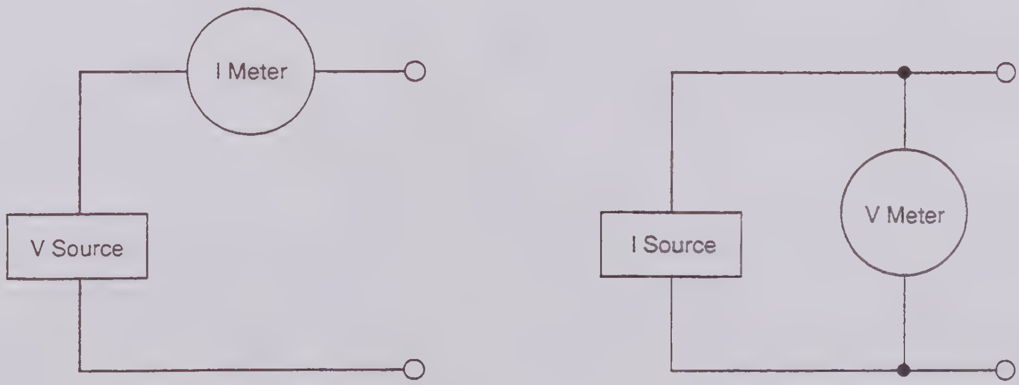
Source-Measure Concepts

1.2 OPERATION OVERVIEW

The fundamental models for the Source Measure Units are shown in Figure 1-1. When programmed to source voltage, the IMETER is connected in series with the VSOURCE and output. When programmed to source current, the VMETER is connected across (in parallel to) the ISOURCE and output.

Source Capabilities

VSOURCE — The Models 236 and 238 can source from ±100µV to ±110V. The Model 237 has an additional source range of ±1100V. The programmable current compliance is up to 100mA for the Model 236, 100mA for the 237 (except 10mA on the 1100V source range), and 1A for the Model 238 (except 100mA on the 110V source range).



A. Source V Measure I

B. Source I Measure V

Figure 1-1. Fundamental Models

ISOURCE — The Models 236 and 237 can source from ±100fA to ±100mA. The Model 238 has an additional source range of ±1A. The programmable voltage compliance is up to 110V for the Model 236, 1100V for the 237 (except 110V on the 100mA source range), and 110V for the Model 238 (except 15V on the 1A source range).

Compliance limits are used to protect external circuitry or DUT (devices under test). Setting an appropriate current compliance (I-limit) can prevent excessive power dissipation in a device. Setting an appropriate voltage compliance (V-limit) can protect a device susceptible to damage by overvoltage. The Source Measure Unit will never exceed the user programmed compliance limit.

Source Only — To use the Source Measure Unit only as a source, simply ignore measure readback (displayed measurements for dc operation, and measure values in the sweep buffer for sweep operation). For IEEE-488 bus operation, measure readback can be disabled (G command).

Measure Capabilities

IMETER — The Model 236 can measure from ±10fA to ±100mA, the Model 237 from ±10fA to ±100mA (except 10mA on the 1100V source range), and the Model 238 from ±10fA to ±1A (except 100mA on the 110V source range).

VMETER — The Model 236 can measure from ±10μV to ±110V, the Model 237 from ±10μV to ±1100V (except 110V on the 100mA source range), and the Model 238 from ±10μV to ±110V (except 15V on the 1A source range).

The selected compliance range is also the maximum measurement range. For example, if compliance is programmed to 50mA (100mA range), measurements (up to 50mA) will be made on the 100mA range. However, if AUTORANGE is enabled, the Source Measure Unit will always go to the lowest (most sensitive) possible range to make the measurement.

Measure Only — The Source Measure Unit can be used as a stand-alone voltmeter or current meter (see Figure 1-2). To measure voltage, select Source I Measure V and set the current source to zero on the 1nA range (0.0000 nA). To measure current, select Source V Measure I and set the voltage source to zero on the 1V range (0.0000 V).

Source-Delay-Measure

Source Measure Unit operation (dc and sweep) consists of a series of source-delay-measure (SDM) cycles (see Figure 1-3). During each SDM cycle, the following occurs:

1. Set the source output level.
2. Perform the delay.
3. Make the measurement.

The delay is used to allow the source to settle before the measurement is made. The total time period of the delay includes an internal (default) delay and the user programmed delay.

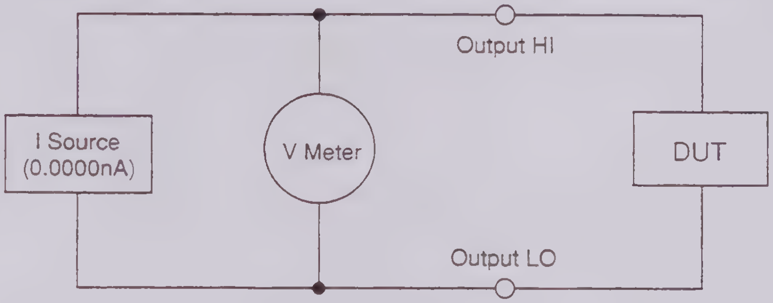
With the default delay enabled, a short delay is used to allow for internal settling on the low current ranges. The default delay is approximately equivalent to five RC time constants of the selected current range for either Source I or Source V.

A programmable delay (from 0msec to 65sec) is available to compensate for longer settling caused by external circuitry. The more capacitance seen at the output, the more settling time that is required for the source. The actual delay period needed can be calculated or determined by trial and error. For resistive loads and higher currents, the programmable delay can be set to 0msec.

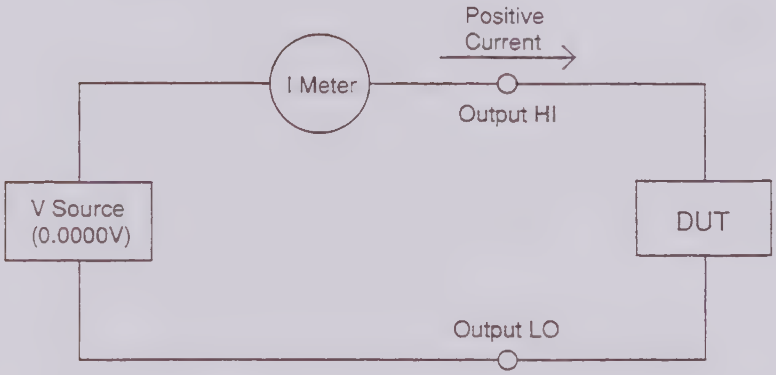
Operating Functions (DC and Sweep)

In dc operation (dc function selected), a constant dc voltage or current is applied to the output. This operation consists of a continuous series of SDM cycles. During each SDM cycle, the measured reading will be internally updated, making them available for display. The programmed source value is displayed on the left side of the display and the subsequent measurement is shown on the right side. All readings are not displayed. The display is slower than the internal measure update rate, however it is possible to get all readings over the bus.

In sweep operation (sweep function selected), the Source Measure Unit sweeps through a user-defined list of points specifying source values and delay times for a waveform (fixed level, staircase or pulse). An SDM cycle


Output HI
I Source
(0.0000nA)
V Meter
DUT
Output LO

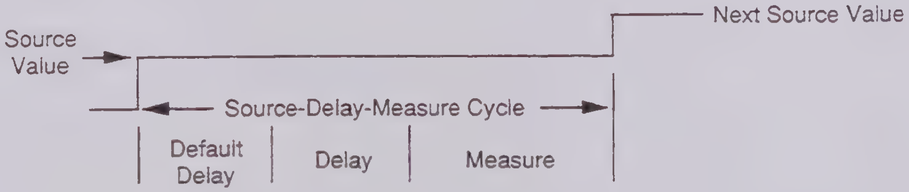
A. Measure Voltage only


Positive
Current
I Meter
Output HI
V Source
(0.0000V)
DUT
Output LO

NOTE : Positive current flowing out of Output HI results in positive (+) measurements.

B. Measure Current only

Figure 1-2. Measure Only


Next Source Value
Source
Value
Source-Delay-Measure Cycle
Default
Delay
Delay
Measure

Default Delay : Fixed delay for instrument settling.

Delay : Additional delay for device under test or system capacitance.

Figure 1-3. Source-Delay-Measure (SDM) Cycle

occurs during each programmed step or point of the sweep. Each measurement in the sweep is stored in the sweep buffer.

Sweep Types

There are six basic sweep waveforms to select from and are shown in Figure 1-4. Source levels, delay times and measurement points of a sweep waveform are programmed by the user. Except for the fixed level sweep, each step (or level) of a sweep waveform consists of a single SDM cycle. Thus, one measurement will be performed at each step (level) and stored in the sweep buffer.

Typical applications for staircase sweeps include; I-V curves for 2- and 3-terminal semiconductor devices, characterization of leakage vs. voltage, and semiconductor breakdown. Pulse sweeps are used in similar applications where thermal response is measured or where sustained power levels can damage the external device under test. The fixed level sweep allows the unit to function as a data logger with a time stamp. The time stamp is available for all sweep types allowing time-dependent effects to be measured.

In addition to the built-in sweeps, the user can append different sweep types together (sweep append) or modify an existing sweep point-by-point (sweep modify) to develop a custom waveform.

Sweep Buffer

After a sweep is run, the data for up to 1000 measurement points is stored in the sweep buffer. This data can be accessed from the front panel, or, over the IEEE-488 bus, sent to a computer for evaluation (i.e. plotting).

Figure 1-5 shows an example of a sweep. The table shows the type of data that is stored in the sweep buffer for every measurement point. The delay column in the table lists the delay period programmed by the user for each step of this sweep. Notice that a different delay was programmed for the fifth step of this modified sweep.

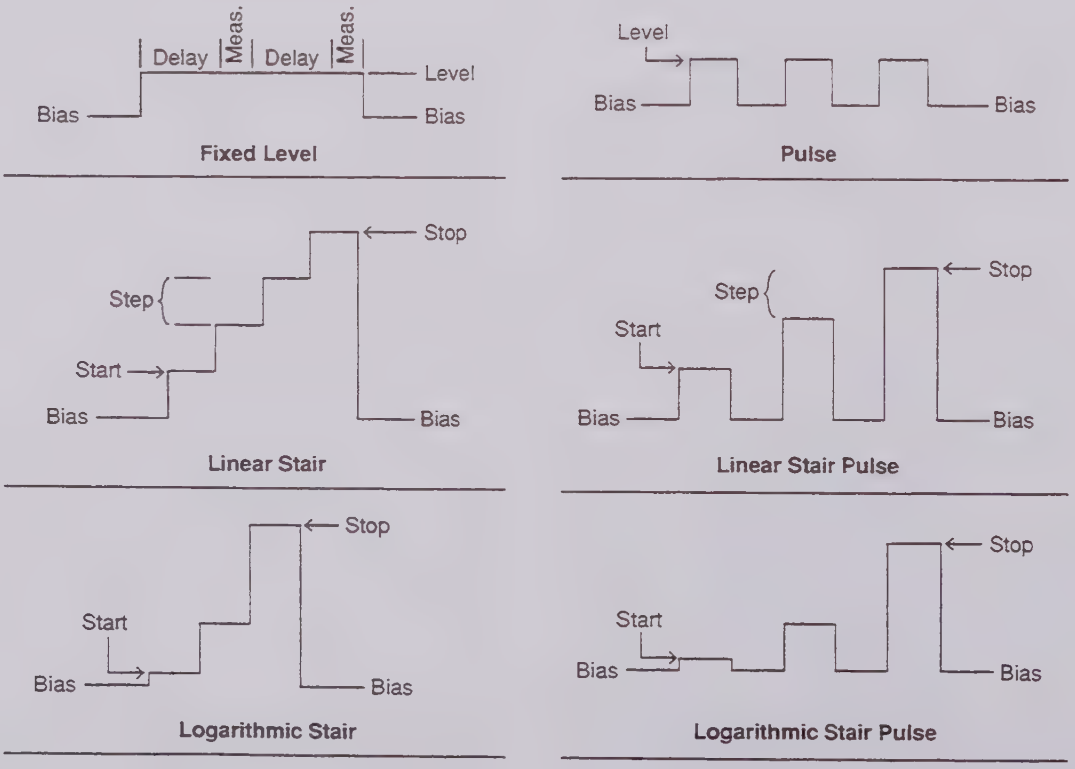
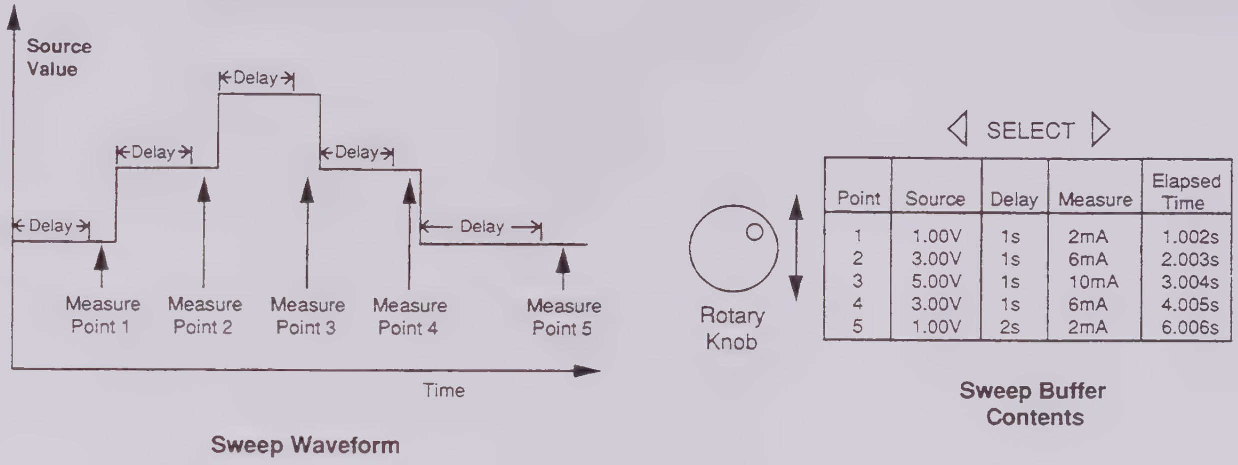

Delay
Meas.
Delay
Meas.
Level
Bias
Bias
Fixed Level
Level
Bias
Bias
Pulse
Stop
Step
Start
Bias
Bias
Linear Stair
Stop
Step
Start
Bias
Bias
Linear Stair Pulse
Stop
Start
Bias
Bias
Logarithmic Stair
Stop
Start
Bias
Bias
Logarithmic Stair Pulse

Figure 1-4. Sweep Waveforms



Point	Source	Delay	Measure	Elapsed Time
1	1.00V	1s	2mA	1.002s
2	3.00V	1s	6mA	2.003s
3	5.00V	1s	10mA	3.004s
4	3.00V	1s	6mA	4.005s
5	1.00V	2s	2mA	6.006s

Figure 1-5. Example Sweep

"Elapsed time" time stamps each measurement of the sweep. Each elapsed time is measured from the beginning of the sweep to the end of the measurement for each point. Notice that in addition to the programmed delay, there is time contributed by other factors, such as the integration time of the measurement. The time stamps are useful when performing V or I versus t tests.

When RECALL is enabled, the data in the sweep buffer is displayed by the Source Measure Unit using the rotary knob and the SELECT buttons. The display serves as a "window" to view each data parameter. As shown in the illustration, the rotary knob moves the display "window" vertically, while the SELECT buttons move the display "window" horizontally.

1.3 BASIC CIRCUIT CONFIGURATIONS

The simple models shown in Figure 1-1 have been expanded to include the driven guard and sense circuits, and are shown in Figure 1-6 and Figure 1-7.

Source I Measure V

To Source I Measure V (see Figure 1-6), a voltmeter (V_{METER}) is connected in parallel with the current source (I_{SOURCE}). In this configuration, the Source Measure Unit will function as a high-impedance current source with voltage measure (and limit) capability.

Sense selection (local or remote) determines where the voltage measurement is made. In local sense, voltage is measured at the output of the Source Measure Unit. In remote sense, voltage is measured at the DUT eliminating any voltage drops that may be in the test leads or connections between the Source Measure Unit and the DUT.

The driven guard needed to accurately source low current is provided by a buffer circuit. The X1 buffer ensures that GUARD and OUTPUT HI always remain at the same potential. Proper use of GUARD virtually eliminates leakage paths in the cable, test fixture and connectors.

Source V Measure I

To Source V Measure I (see Figure 1-7), an ammeter (I_{METER}) is connected between the voltage source (V_{SOURCE}) and OUTPUT HI. In this configuration, the Source Measure Unit will function as a low-impedance voltage source with current measure (and limit) capability.

Sense circuitry is used to constantly monitor the output voltage and make adjustments to V_{SOURCE} as needed. V_{METER} measures the voltage at the output (local sense) or at the DUT (remote sense) and compares it to the programmed voltage level. If the sensed (measured) level and the programmed value are not the same, V_{SOURCE} is adjusted accordingly. Here again, remote sense eliminates the effect of voltage drops in the test leads ensuring that the exact programmed voltage appears at the DUT.

The driven guard needed to accurately measure low current is provided by the X1 buffer circuit. GUARD and OUTPUT HI will always be at the same potential.

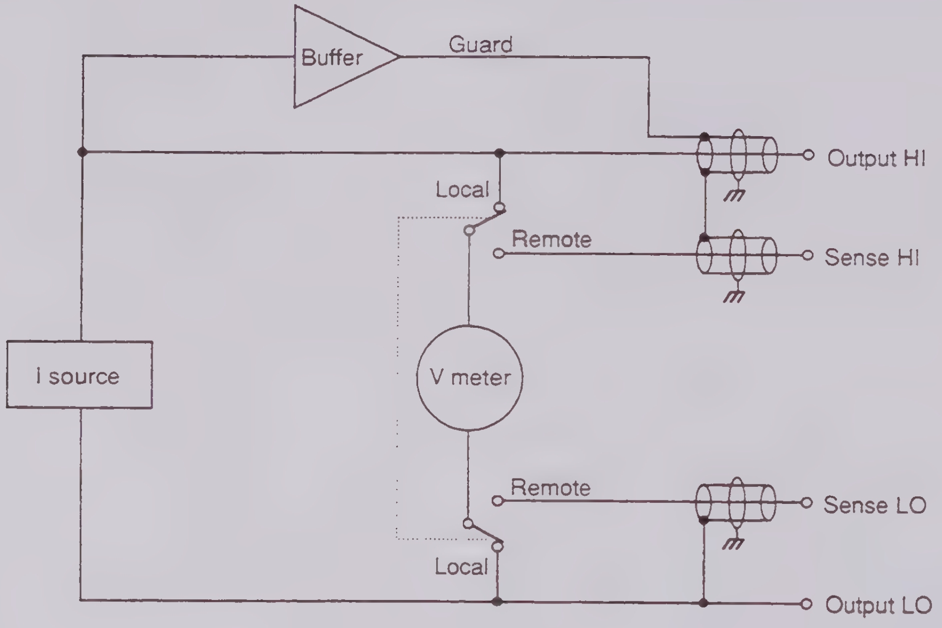

Buffer
Guard
Output HI
Local
Remote
Sense HI
I source
V meter
Remote
Sense LO
Local
Output LO

Figure 1-6. Source I Measure V

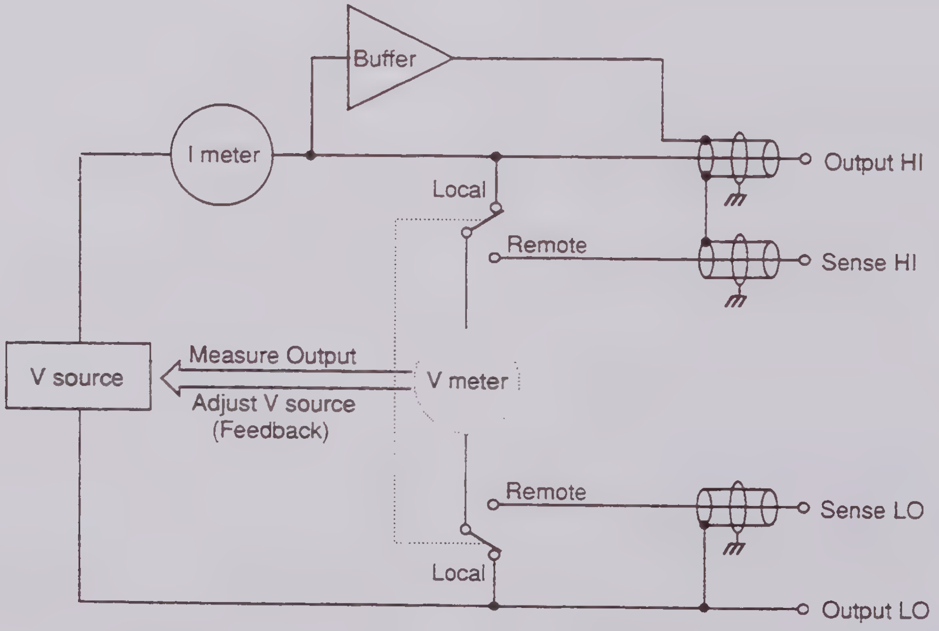

Buffer
I meter
Output HI
Local
Remote
Sense HI
V source
Measure Output
V meter
Adjust V source
(Feedback)
Remote
Sense LO
Local
Output LO

Figure 1-7. Source V Measure I

1.4 GUARD AND REMOTE SENSING

Guard

The purpose of guarding is to eliminate the effects of leakage current (and capacitance) that exists between output high and output low. In the absence of a driven guard, leakage could be enough to adversely affect the performance of the Source Measure Unit.

Effective guarding is achieved by surrounding output high with a driven guard. Since the voltage potentials of output high and the driven guard are the same, virtually no leakage current can flow from output high to output low.

The Source Measure Unit provides a driven guard for OUTPUT HI and SENSE HI. The driven guard is always enabled and thus, always available at the rear panel of the Source Measure Unit. When the Source Measure Unit is properly connected to a test fixture (such as the 8006), guard is extended to that test fixture. Thus, leakage in the connecting triax cables is virtually eliminated. Inside the test fixture, coaxial cables can be used to extend guard all the way to the DUT.

Guard should always be used when sourcing or measuring low current (<1μA) or for high speed measurements (SDM cycle <10msec).

WARNING

GUARD is at the same potential as OUTPUT HI. Thus if lethal voltages are present at OUTPUT HI, they are also present at GUARD.

Remote Sense

The Source Measure Unit has local or remote sensing capability. When using remote sensing, sense lines are extended to the DUT.

When sourcing V, remote sensing allows the voltage to be sensed (measured) at the load for better regulation. If the remotely sensed voltage at the DUT is lower than the programmed voltage level (due to test lead IR drop), the actual output voltage will be increased until the sensed voltage equals the programmed voltage. This ensures that the exact programmed voltage appears at the DUT.

When sourcing I, remote sensing performs the voltage measurement right at the DUT. The measured reading is the actual voltage across the DUT and does not include the IR drop of the test leads.

Remote sensing should be used when sourcing or measuring 1mA or more.

WARNING

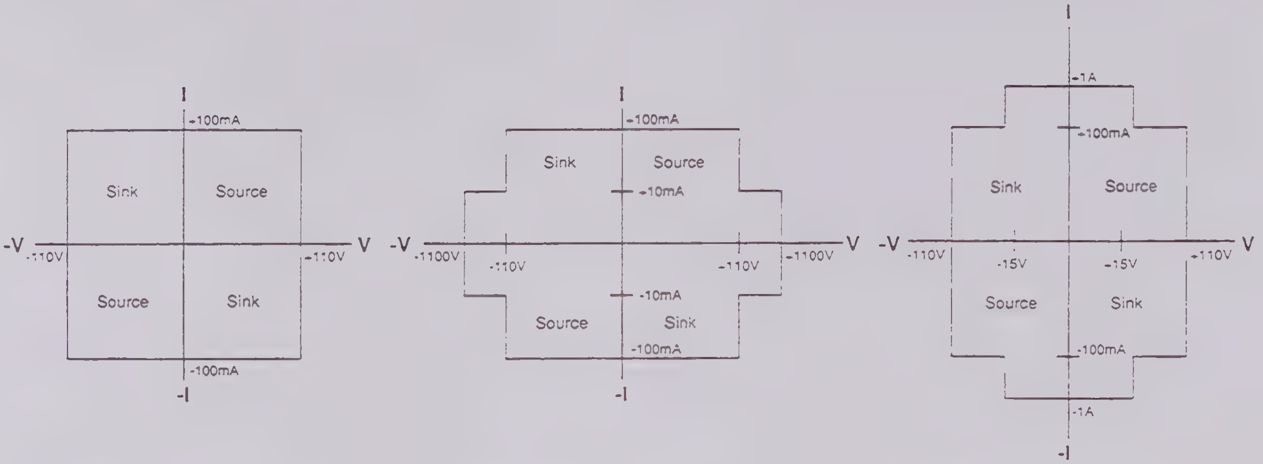
With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

1.5 OPERATING BOUNDARIES

Depending on how it is programmed and what is connected to the output (passive or active load), the Source Measure Unit can operate in any of the four quadrants. The source-measure capabilities of the Models 236, 237, and 238 are summarized in Figure 1-8. From these graphs, it can be determined that if the Models 236, 237, and 238 are sourcing 110V, they can measure (and limit) up to 100mA. Conversely, if they are sourcing 100mA they can measure (and limit) up to 110V.

Figure 1-8B shows the extended capabilities of the Model 237. When sourcing over 110V (up to 1100V), it can measure (and limit) 10mA. Conversely, when sourcing 10mA or less, it can measure (and limit) 1100V. Figure 1-8C shows the extended capabilities of the Model 238. When sourcing over 100mA (up to 1A), it can measure (and limit) 15V. Conversely, when sourcing 15V or less, it can measure (and limit 1A).

When operating in the first or third quandrant, the Source Measure Unit is operating as a source. That is, the Source Measure Unit is delivering power to a load. When operating in the second or fourth quadrant, the Source Measure Unit is operating as a sink. As a sink, it is dissipating power rather than sourcing it. An external source or an energy storage device, such as a capacitor or a battery, can force operation in the sink region. For example, if a 12V battery is connected to a Source Measure Unit (Output HI to battery high) that is programmed for +10V,


I
+100mA
Sink
Source
-V
-110V
+110V
V
Source
Sink
-100mA
-I
I
+100mA
Sink
Source
+10mA
-V
-1100V
-110V
+110V
+1100V
V
-10mA
Source
Sink
-100mA
-I
I
+1A
+100mA
Sink
Source
-V
-110V
-15V
+15V
+110V
V
Source
Sink
-100mA
-1A
-I

A. Model 236　**B. Model 237**　**C. Model 238**

Figure 1-8. Source-Measure Capabilities

sink operation will occur in the second quadrant (source +V and measure –I).

Source I Measure V

The operating boundaries in a single quadrant for Source I Measure V are shown in Figure 1-9. The voltage limit load line represents the programmed compliance limit set by the user. The current source load line represents the source current programmed by the user. These load lines are boundary lines that represent the operating limits of the Source Measure Unit for this quadrant of operation. The operating boundaries for the other three quadrants are similar.

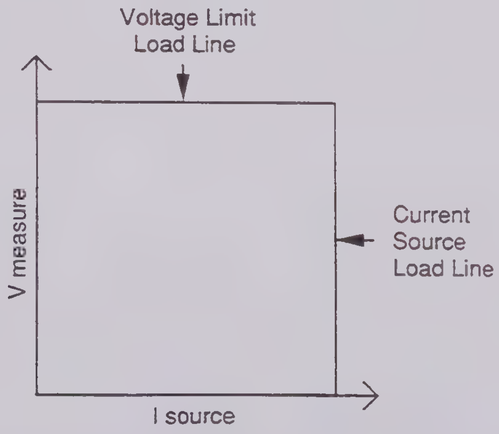

Voltage Limit
Load Line
V measure
Current
Source
Load Line
I source

Figure 1-9. I-Source Operating Boundaries

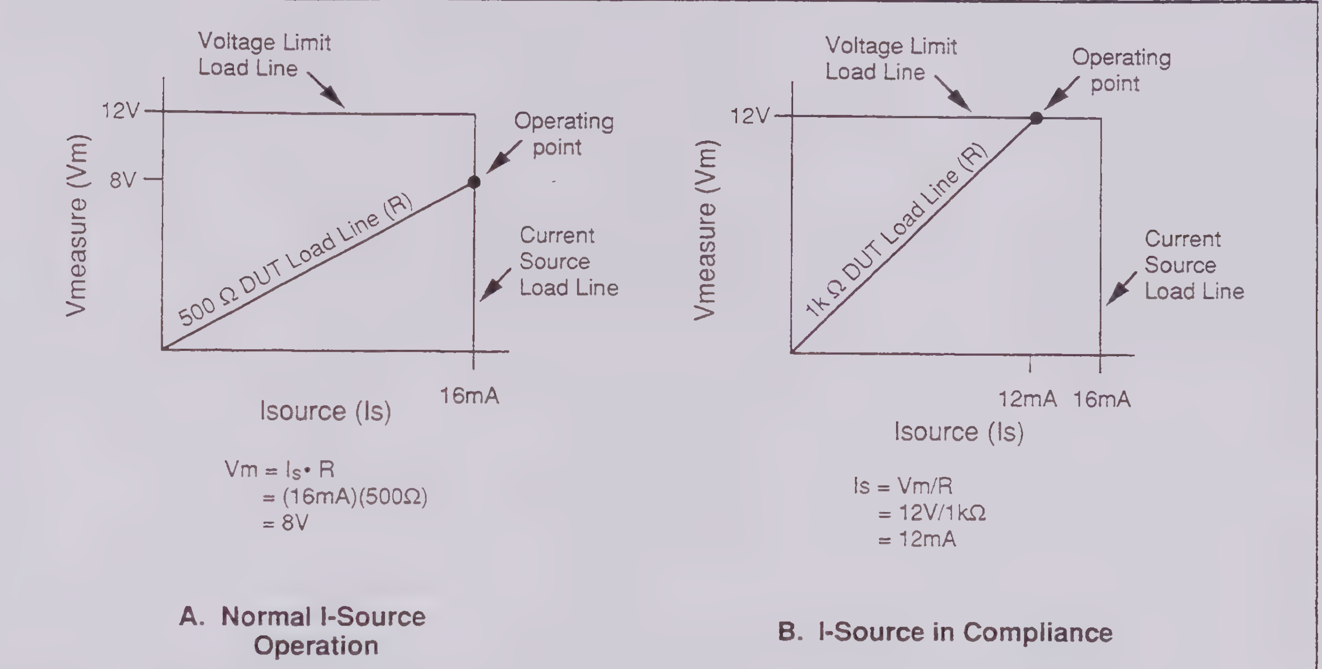
Where on the boundary the Source Measure Unit operates depends on the load (DUT) that is connected to its output. Figure 1-10 shows operation examples for resistive loads that are 500Ω and 1kΩ respectively. In these examples, the Source Measure Unit is programmed to source 16mA and limit (measure) 12V.

In Figure 1-10A, the Source Measure Unit is sourcing 16mA to the 500Ω load and subsequently measures 8V. As long as the DUT load line intersects the current source load line, the Source Measure Unit will be able to source its programmed current (16mA).

Figure 1-10B shows what happens if the resistance of the load is increased to 1kΩ. The DUT load line intersects the voltage limit load line placing the Source Measure Unit in compliance. In compliance, the Source Measure Unit will not be able to source its programmed current (16mA). Instead, it will source only 12mA.

Notice that as resistance increases, the slope of the DUT load line increases. As resistance approaches infinity (open output), the Source Measure Unit will source virtually 0mA at 12V. Conversely, as resistance decreases, the slope of the DUT load line decreases. At zero resistance (shorted output), the Source Measure Unit will source 16mA at virtually 0V.

Regardless of the load, voltage will never exceed the programmed compliance of 12V. Also, maximum power to a DUT in this case will never exceed 192mW (12V X 16mA).


Voltage Limit Load Line
12V
8V
Vmeasure (Vm)
Operating point
500 Ω DUT Load Line (R)
Current Source Load Line
16mA
Isource (Is)
Vm = I_S• R
= (16mA)(500Ω)
= 8V
Voltage Limit Load Line
Operating point
12V
Vmeasure (Vm)
1k Ω DUT Load Line (R)
Current Source Load Line
12mA
16mA
Isource (Is)
Is = Vm/R
= 12V/1kΩ
= 12mA

A. Normal I-Source Operation

B. I-Source in Compliance

Figure 1-10. I-Source Operation Examples

Source V Measure I

The operating boundaries in a single quadrant for Source V Measure I is shown in Figure 1-11. The current limit load line represents the programmed compliance limit programmed by the user. The voltage source load line represents the source voltage programmed by the user. These load lines are boundary lines that represent the operating limits of the Source Measure Unit for this quadrant of operation. The operating boundaries for the other three quadrants are similar.

Where on the boundary the Source Measure Unit operates depends on the load (DUT) that is connected to its output. Figure 1-12 shows operation examples for resistive loads that are 500Ω and 200Ω respectively. In these examples, the Source Measure Unit is programmed to source 10V and limit (measure) 25mA.

In Figure 1-12A, the Source Measure Unit is sourcing 10V to the 500Ω load and subsequently measuring 20mA. As long as the DUT load line intersects the voltage source load line, the Source Measure Unit will be able to source its programmed voltage (10V).

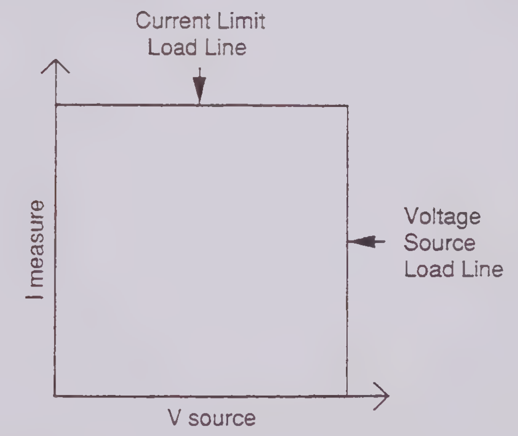

Current Limit Load Line
I measure
Voltage Source Load Line
V source

Figure 1-11. V-Source Operating Boundaries

Figure 1-12B shows what happens if the resistance of the load is decreased to 200Ω. The DUT load line intersects the current limit load line placing the Source Measure Unit in compliance. In compliance, the Source Measure Unit will not be able to source its programmed voltage (10V). Instead, it will source only 5V.

Notice that as resistance decreases, the slope of the DUT load line increases. At zero resistance (shorted output), the Source Measure Unit will source virtually 0V at

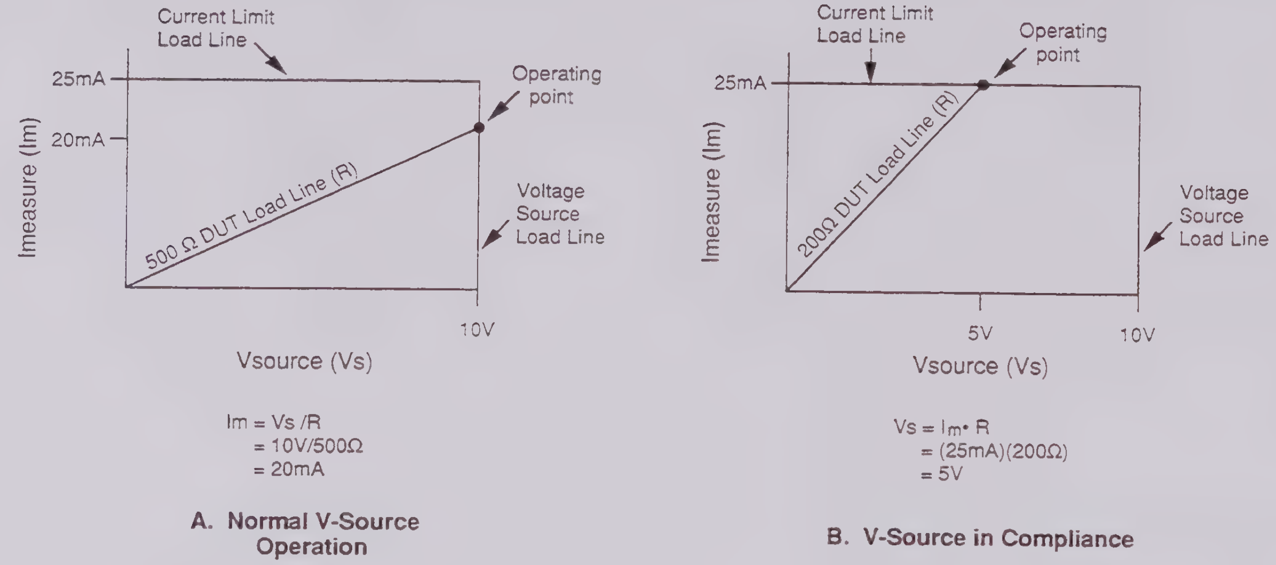


Figure 1-12. V-Source Operation Examples

25mA. Conversely, as resistance increases, the slope of the DUT load line decreases. At infinite resistance (open output), the Source Measure Unit will source 10V at virtually 0mA.

Regardless of the load, current will never exceed the programmed compliance of 25mA. Also, maximum power to a DUT in this case will never exceed 250mW (10V X 25mA).

Front and Rear Panel Familiarization

1.6 FRONT PANEL FAMILIARIZATION
1.7 REAR PANEL FAMILIARIZATION

Front and Rear Panel Familiarization

1.6 FRONT PANEL FAMILIARIZATION

The front panel of the Model 237 Source Measure Unit is shown in Figure 1-13, along with a brief description of each item. The display and front panel controls of the Model 236 and 238 are not shown since they are similar to the Model 237.

In the source-measure display state, the left side of the display provides the programmed source value while the right side provides the subsequent measured reading. When not displaying values, the 18-character display is used for messages associated with various aspects of operation.

All front panel controls, except for the POWER switch and the rotary knob, are momentary contact switches. Many control buttons have a light to indicate the selected feature. The controls are color-coded into functional groups for ease of operation.

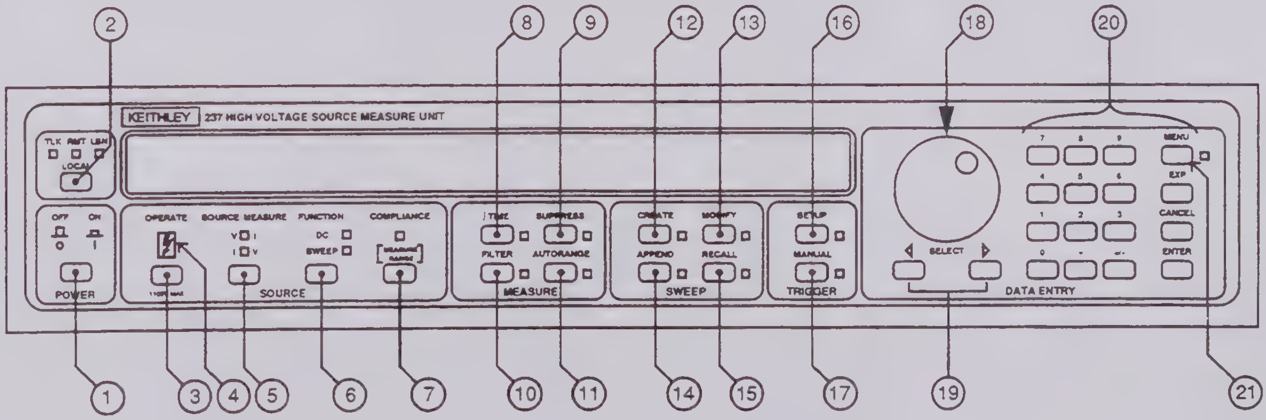

②
⑧
⑨
⑫
⑬
⑯
⑱
⑳
KEITHLEY
237 HIGH VOLTAGE SOURCE MEASURE UNIT
TLK
RMT
LSN
LOCAL
OFF
ON
POWER
OPERATE
SOURCE MEASURE
V I
I V
FUNCTION
DC
SWEEP
COMPLIANCE
MEASURE RANGE
SOURCE
TIME
SUPPRESS
FILTER
AUTORANGE
MEASURE
CREATE
MODIFY
APPEND
RECALL
SWEEP
SETUP
MANUAL
TRIGGER
SELECT
7
8
9
MENU
4
5
6
EXP
1
2
3
CANCEL
0
.
+/-
ENTER
DATA ENTRY
①
③
④
⑤
⑥
⑦
⑩
⑪
⑭
⑮
⑰
⑲
㉑

Figure 1-13. Model 237 Front Panel

① **POWER** — This switch controls ac power to the Source Measure Unit. Power is ON when the switch set is to the "in" (1) position, and OFF when the switch is set to the "out" (0) position.

② **LOCAL** — IEEE-488 Interface Control. Pressing this button when the unit is in remote (REMOTE on) returns the unit to the local mode (REMOTE off) and restores operation of other front panel controls unless LLO (local lockout) is in effect.

SOURCE GROUP

③ **OPERATE** — This toggle-action button places the instrument in the operate or standby state. In operate (OPERATE light on), the selected source parameter (if triggered) will be available at the output. In standby, 0V is applied to the output and the message "STDBY" is displayed.

④ ⚡ **WARNING** — Operate indicator for Model 237. Up to 1100V may be present on output connections when lit.

⑤ **SOURCE MEASURE** — This toggle-action button selects the voltage source or the current source. When set to source V, the Source Measure Unit will measure I. Conversely, when set to source I, V will be measured. Note that pressing this button will take the instrument out of operate and place it in standby. Also, it will place the unit in an untriggered state.

⑥ **FUNCTION** — This toggle-action button selects dc or sweep operation.

⑦ **COMPLIANCE** — This button is used to check/change the compliance level. With the Source Measure Unit set to source V, the current compliance level is displayed, and conversely, when set to source I, the voltage compliance level is displayed. With the compliance displayed, its value can be changed using either the adjust (rotary knob) or edit (keypad) method. The instrument returns to normal operation when a keypad value is entered or the COMPLIANCE button is again pressed.

Note: Selecting a compliance range also sets the maximum Source Measure Unit measurement range.

MEASURE GROUP

⑧ **∫ TIME** — When this button is pressed, the present integration period is displayed. An alternate integration period (fast, medium or line cycle) can be selected by displaying it with the SELECT buttons and then pressing ENTER. If the period is not to be changed, again press ∫ TIME to return to normal operation.

FAST = 416µsec; 4-digit resolution
MEDIUM = 4msec; 5-digit resolution
LINE CYCLE = 16.667msec or 20msec; 5-digit resolution

⑨ **SUPPRESS** — When this button is pressed, the next conversion will be internally stored as a baseline. All subsequent readings will be the difference between the suppressed value and the actual signal level.

⑩ **FILTER** — When this button is pressed, the status of the measurement filter is displayed. To change the amount of filtering, display the desired filter (disable, 2, 4, 8, 16 or 32 readings averaged) using the SELECT buttons and then press ENTER. Indicator is on when the FILTER is enabled.

⑪ **AUTORANGE** — This button enables AUTORANGE. With AUTORANGE enabled, the Source Measure Unit will go to the lowest (most sensitive) possible range to make the measurement.

SWEEP GROUP

⑫ **CREATE** — Sweep CREATE selects a sweep and defines its parameters. In general, when this button is pressed, one of the available sweeps will be displayed. If an alternate sweep is desired, use the SELECT buttons to display it and then press ENTER. The rotary knob is then used to display the parameters while the keypad is used to change them.

⑬ **MODIFY** — Sweep MODIFY makes modifications to a sweep that already exists. With sweep modify, the source value and/or delay time can be modified at any individual data point of the sweep.

When MODIFY is pressed the source (SRC) value at the first data point is displayed. The source value at this point can be modified by keying in a value and pressing ENTER. The source range will then be displayed and can be changed using the SELECT buttons and pressing ENTER. Pressing the SELECT ▶ button will display the delay (DLY) time. This delay can also be modified. The rotary knob scrolls the display to other data points for similar modifications. Exit modify by again pressing MODIFY.

⑭ **APPEND** — Sweep APPEND adds a sweep to a sweep that already exists. Pressing APPEND will display the sweep in memory. The rotary knob will display the existing parameters of the sweep. Entering the parameters as they are will add an identical sweep to the one in memory. However, the parameters can be changed (via keypad) to add a sweep that is different from the original.

A different sweep type can be appended to the one in memory. With the current sweep type displayed, a different sweep type can be selected with the SELECT buttons. However, non-pulse sweeps cannot be appended to pulse sweeps, and vice versa. The parameters for this additional sweep are then defined using the rotary knob and keypad.

⑮ **RECALL** — After a sweep is run, pressing RECALL will display the first entry of the last data point of the sweep. The stored data are organized in a matrix array. In general, the display "window" is moved across the matrix using the SELECT buttons, and up and down the matrix using the rotary knob. Pressing RECALL a second time returns the Source Measure Unit to normal operation.

Before a sweep is run, RECALL can be used to view source values created for the sweep.

TRIGGER GROUP

⑯ **SETUP** — After pressing SETUP, the current status of the triggers can be displayed with the rotary knob. With a trigger displayed, its parameters can be changed with SELECT and ENTER. Press SETUP and then ENTER to enter new trigger parameters.

⑰ **MANUAL** — When the MANUAL trigger light is blinking, a trigger stimulus is required. This trigger stimulus can be provided by pressing the MANUAL trigger button, sending an appropriate trigger command over the IEEE bus, or by receiving an external input trigger.

DATA ENTRY GROUP

⑱ **Rotary Knob** — Controls the display of various operating parameters, adjusts source and compliance values, and when in RECALL, controls the display of sweep data.

⑲ **SELECT** — These buttons select alternate operating parameters and, when in RECALL, controls the display of sweep data.

⑳ **Keypad** — All keypad buttons, except MENU, enter (or cancel) numeric data.

㉑ **MENU** — Used to check/change parameters of the following operating conditions: dc delay (0 to 65sec), default delay (on/off), sense (local/remote), line frequency setting (50Hz/60Hz) and IEEE address (0 to 30). Also used to run self-tests.

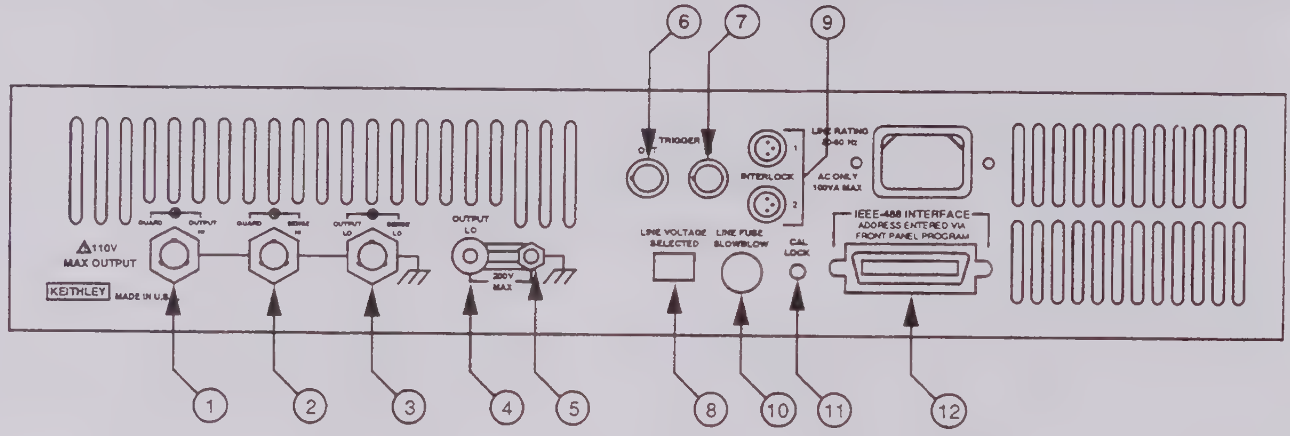

6
7
9
TRIGGER
OUT
INTERLOCK
1
2
LINE RATING
50-60 Hz
AC ONLY
100VA MAX
IEEE-488 INTERFACE
ADDRESS ENTERED VIA
FRONT PANEL PROGRAM
GUARD
OUTPUT
HI
GUARD
SENSE
HI
OUTPUT
LO
SENSE
LO
OUTPUT
LO
200V
MAX
110V
MAX OUTPUT
KEITHLEY
MADE IN U.S.A.
LINE VOLTAGE
SELECTED
LINE FUSE
SLOWBLOW
CAL
LOCK
1
2
3
4
5
8
10
11
12

Figure 1-14. Model 236 Rear Panel

1.7 REAR PANEL FAMILIARIZATION

The rear panel of the Model 236 Source Measure Unit is shown in Figure 1-14.

① **OUTPUT HI (GUARD)** — OUTPUT HI (GUARD) is a three-lug triax connector. OUTPUT HI is located on the center conductor and GUARD is located on the inner shell.

② **SENSE HI (GUARD)** — SENSE HI (GUARD) is a three-lug triax connector. SENSE HI is located on the center conductor and GUARD is located on the inner shell.

③ **SENSE LO (OUTPUT LO)** — SENSE LO (OUTPUT LO) is a three-lug triax connector. SENSE LO is located on the center conductor and OUTPUT LO is located on the inner shell.

④ **OUTPUT LO** — Five-way binding post for OUTPUT LO.

⑤ **CHASSIS GROUND** — This binding post is connected to chassis ground. For optimum shielding OUTPUT LO must be connected to this connector (ground link installed). Only remove the ground link for floating operation.

WARNING

Never use the chassis ground binding post as a safety earth ground. This is strictly a "source-measure" terminal and not a safety terminal.

⑥ **TRIGGER OUT** — TRIGGER OUT is a BNC connector. Provides negative edge TTL pulses. Referenced to IEEE (chassis) common. Can be used to trigger other Source Measure Unit operations.

⑦ **TRIGGER IN** — TRIGGER IN is a BNC connector. Receives negative edge TTL level triggers. Referenced to chassis common.

⑧ **LINE VOLTAGE** — Two-position slide switch. Set to available line power (115V or 230V).

⑨ **INTERLOCK** — Two 3-pin male connectors. One connects to the test fixture and the other can be connected to a second Source Measure Unit. Cable connection to the Source Measure Unit enables the interlock feature. Used to place Source Measure Unit(s) in standby when lid of test fixture is opened.

WARNING

When using the INTERLOCK feature in a multiple unit test system, make sure all the

Model 236/237/238s remain powered up. Turning off one or more Model 236/237/238s in the test system may result in erratic INTERLOCK operation. That is, an operational Model 236/237/238 may not go into standby when the lid of the system test fixture is opened. This condition exposes the operator to potentially lethal voltages that could result in injury or death.

As a general rule of safety for multiple unit interlocked test systems, either keep all Model 236/237/238s powered on, or turn them all off.

⑩ LINE FUSE — Provides protection on the ac power line input.

⑪ CAL LOCK — Source Measure Unit calibration cannot be saved with this pushbutton switch in the OUT position.

⑫ **IEEE-488** — Connects the instrument to the IEEE-488 bus.

Basic Source-Measure Techniques

1.8 POWER UP
1.9 CONNECTIONS
1.9.1 Source Measure Unit Connections to Test Fixture
1.9.2 Test Connections
1.10 SOURCE-MEASURE EXAMPLES
1.10.1 Dc Operation Example — Resistor Test
1.10.2 Sweep Operation Example — Zener Diode Test

Basic Source-Measure Techniques

1.8 POWER UP

The following abbreviated information should be enough to properly and safely power up the unit. However, if there are any uncertainties, refer to paragraph 2.2 for the complete power up procedure.

Line Voltage

The Source Measure Unit is designed to operate from 105-125V or 210-235V line power ranges. The operating voltage that the instrument is configured to operate at is indicated on the line voltage slide switch located on the rear panel (see Figure 1-15). If the alternate line voltage setting is required, a fuse change will be required. The procedure to configure the instrument to operate at the alternate line voltage is located in paragraph 2.2.1.

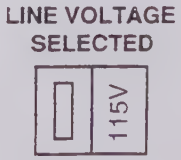


Figure 1-15. Line Voltage Selected

Power Cord

Connect the female end of the power cord to the ac receptacle on the rear panel of the instrument. Connect the male end of the cord to a grounded ac outlet.

WARNING

The Source Measure Unit is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in injury or death due to electric shock.

CAUTION

Be sure that the power line voltage agrees with the indicated range on rear panel line voltage switch. Failure to observe this precaution may result in instrument damage not covered by the warranty. The procedure to configure the instrument for the alternate line voltage is found in paragraph 2.2.

Power Up Cycle

To turn on the instrument, press the POWER button. The Source Measure Unit will briefly display the installed software revision and the IEEE-488 bus address setting. Complete details on the power up cycle, which includes self tests, are contained in paragraph 2.2.4.

Line Frequency

The instrument will operate at a line frequency of 50 or 60Hz. If the line frequency setting of unit is in question, proceed to paragraph 2.2.6 to check and, if necessary, change it.

1.9 CONNECTIONS

The Source Measure Unit is intended to be used with a test fixture for DUT in order to maintain safety and optimize performance. The operating examples in this section use the Keithley Model 8006 test fixture which is designed to be used with the Source Measure Unit. However, an alternate test fixture can be used as long as the following safety criteria are followed:

- The test fixture must be completely enclosed to prevent human access to live circuitry.
- The test fixture must use a safety interlock such that all power connected to it will be interrupted when it is opened.
- The chassis of the test fixture must be connected to a safety earth ground to prevent shock hazards.

1.9.1 Source Measure Unit Connections to Test Fixture

Source Measure Unit connections to the Model 8006 test fixture are shown in Figure 1-16. Notice that all three triax connectors of the Source Measure Unit are connected to the test fixture. These connections extend guard and remote sense to the test fixture. The cables used for these connections are 3-slot triax cables.

The interlock feature of the Source Measure Unit is enabled when the interlock cable is connected to it. With this feature, the Source Measure Unit will go into standby whenever the lid of the test fixture is open or ajar.

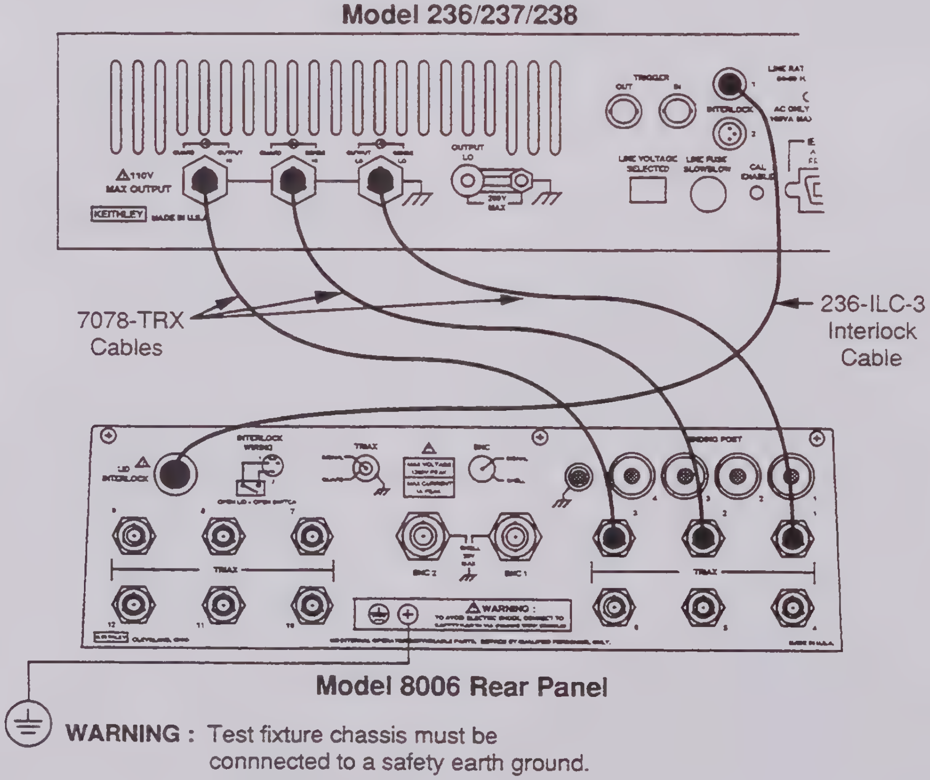

Model 236/237/238
110V MAX OUTPUT
KEITHLEY
OUTPUT LO
TRIGGER
OUT
IN
INTERLOCK
LINE VOLTAGE SELECTED
LINE FUSE SLOWBLOW
7078-TRX Cables
236-ILC-3 Interlock Cable
TRIAX
BNC
Model 8006 Rear Panel
WARNING : Test fixture chassis must be connnected to a safety earth ground.

Figure 1-16. SMU Connections to Test Fixture

1.9.2 Test Connections

All test connections are made at the connection panels of the Model 8006. It is at these panels where guard and remote sense are extended to the DUT, if needed.

Since the two test examples in this section have different requirements, two test connection configurations are shown. Figure 1-17 shows the configuration required to test the resistor (dc example), and Figure 1-18 shows the configuration required to test the zener diode (sweep example).

For the zener diode test, remote sensing is used. Jumpers (supplied with the Model 8006) are used to make connections to the zener diode. Note that jumpers are also used to connect the panel shield and module shield of the test fixture to OUTPUT LO. This provides additional shielding for the DUT.

For the resistor test, remote sensing and guard is not used. Again, the panel shield and module shield of the test fixture are connected to OUTPUT LO.

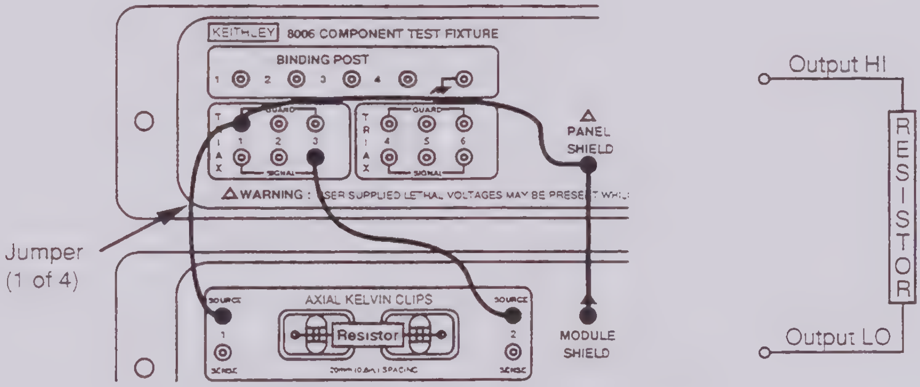

KEITHLEY 8006 COMPONENT TEST FIXTURE
BINDING POST
1
2
3
4
GUARD
TRIAX
SIGNAL
PANEL SHIELD
WARNING :
Jumper (1 of 4)
AXIAL KELVIN CLIPS
SOURCE
SENSE
Resistor
MODULE SHIELD
Output HI
RESISTOR
Output LO

Figure 1-17. Connections for Resistor Test (Remote Sensing)

1.10 SOURCE-MEASURE EXAMPLES

To teach the basics of front panel operation, two simple operating examples are presented here. For dc operation, the Source Measure Unit is used to source I and measure V to test the accuracy of a resistor (100kΩ). For sweep operation, a linear staircase voltage sweep is used to examine the breakdown region of a zener diode.

For those familiar with the IEEE-488 bus, an HP BASIC 4.0 program is provided to repeat each test over the bus. At the factory, the IEEE address of the Models 236, 237, and 238 are set to 16. The IEEE address is briefly displayed on power up.

NOTE

The Source Measure Unit can be used immediately after it is turned on. However, to achieve rated accuracy, the Source Measure Unit must be warmed up for one hour.

1.10.1 Dc Operation Example — Resistor Test

In this test, the Source Measure Unit will be used to source 100µA through a 100kΩ resistor. The subsequent voltage drop (≈10V) across the resistor will be measured and displayed by the Source Measure Unit.

Connect the Source Measure Unit to the Model 8006 test fixture as shown in Figure 1-16, and connect the resistor as shown in Figure 1-17.

Front Panel Operation

Step 1 — Select Current Source

Press the SOURCE MEASURE button to select Source I Measure V

This button toggles between the voltage source and the current source

SOURCE MEASURE
V ☐ I
I ▨ V

Indicator denotes the selected source.

Step 2 — Select dc Function

Press FUNCTION to select the dc function.

This button toggles between dc operation and sweep operation.

FUNCTION
DC ▨
SWEEP ☐

Indicator denotes the selected function.

Step 3 — Enter Source Value

A. Use the Data Entry keypad to key in +100µA.

+100E - 6 AMPS

To key in "E", press EXP button.

B. Press ENTER

C. Press MANUAL TRIGGER if its indicator is blinking.

MANUAL TRIGGER light stops blinking and 100µA source value displayed.

+100.00µA ST.BY V

Step 4 — Enter Compliance Value

A. Press COMPLIANCE.

The present compliance value is displayed.

B. Use keypad to key in 11V.

+11 VOLTS

C. Press ENTER.

Step 5 — Enter Filter

A. Press FILTER.

Present filter status is displayed and indicator is turned on.

B. Use SELECT buttons to select 8 reading filter.

8 RDG FILTER

Average and display 8 measurements. Result is a quieter display reading.

C. Press ENTER.

FILTER indicator remains on to denote that a filter is selected (not disabled).

Step 6 — Select Local Sense

A. Press MENU and use rotary knob to display present sense selection.

B. If in remote sense, press SELECT to display local sense.

SELECT buttons toggle between local and remote sense.

LOCAL SENSE

C. Press ENTER and then MENU.

Step 7 — Source Current and Measure Voltage

Press OPERATE

Indicator denotes that OPERATE is enabled.

+100.00µA +10.000V

Display for an exact 100kΩ load; 100µA sourced and 10V measured.

Step 8 — Adjust I Source Value

ADJUST METHOD

A. Use SELECT buttons to enable cursor and place it on digit to adjust,

Flashing digit indicates position of cursor.

SELECT buttons can also be used to change source range.

B. Use rotary knob to adjust displayed source value.

Output will update as soon as the displayed source value is changed.

EDIT METHOD

A. Use keypad to key in new source value.

B. Press ENTER.

Output will not update until ENTER is pressed.

NOTE: Increasing I to >110 µA will place unit in compliance (COMPLIANCE indicator blinks).

Step 9 — Standby

Press OPERATE to place unit in standby.

IEEE-488 Bus Operation

The following HP BASIC 4.0 program will perform the resistor test from over the IEEE-488 bus. This program is written for a Source Measure Unit that is set to an IEEE address of 16.

```
 10   REMOTE 716
 20   DIM A$ [100]
 30   CLEAR 716
 40   OUTPUT 716; "F1,0X"          Source I Measure V (dc)
 50   OUTPUT 716;                  Source; 100µ A, auto-
      "B100E–6,0,X"                range.
 60   OUTPUT 716; "L11,0X"         Compliance; 11V, auto-
                                   range
 70   OUTPUT 716; "P3X"            Filter 8
 80   OUTPUT 716; "O0X"            Local sensing
 90   OUTPUT 716; "N1X"            Operate
100   OUTPUT 716; "H0X"            Trigger measurement
110   OUTPUT 716; "G15,0,0X"       Output data and talk
120   ENTER 716; A$                Talk
130   PRINT A$                     Display one line of data
140   END
```

After this program is run, the Source Measure Unit will source 100µA to the 100kΩresistor and measure approximately 10V. Also, the output data string will be output to the computer and displayed on the CRT.

1.10.2 Sweep Operation Example — Zener Diode Test

In this test, the Source Measure Unit will be used to source V and measure I. A linear staircase sweep from –6V to –7V in 100mV steps (see Figure 1-19) will be used to collect current measurements in the breakdown region of a 6.3V, 400mW zener diode.

Connect the Source Measure Unit to the test fixture as shown in Figure 1-16, and connect the zener diode as shown in Figure 1-18.

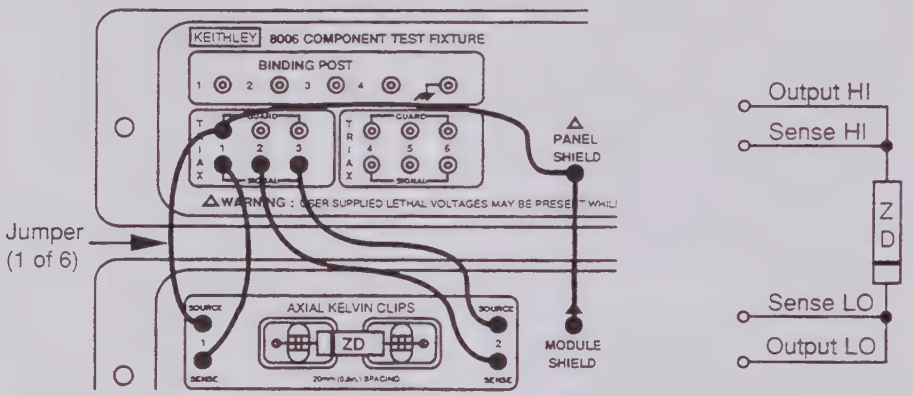

KEITHLEY
8006 COMPONENT TEST FIXTURE
BINDING POST
1
2
3
4
TRIAX
GUARD
1
2
3
SIGNAL
TRIAX
GUARD
4
5
6
SIGNAL
PANEL SHIELD
WARNING : USER SUPPLIED LETHAL VOLTAGES MAY BE PRESENT WHIL
Jumper
(1 of 6)
AXIAL KELVIN CLIPS
SOURCE
1
SENSE
ZD
20mm (0.8in.) SPACING
SOURCE
2
SENSE
MODULE SHIELD
Output HI
Sense HI
Z
D
Sense LO
Output LO

Figure 1-18. Connections for Zener Diode Test (Remote Sensing)

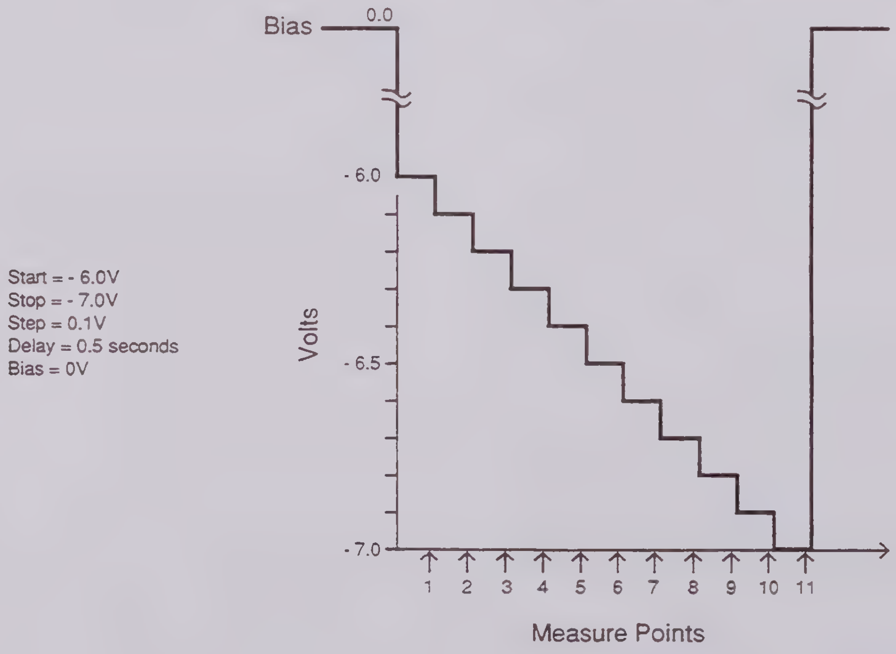


Figure 1-19. Linear Staircase Sweep for Zener Diode Test

Front Panel Operation

Step 1 — Select Voltage Source

Press the SOURCE MEASURE button to select Source V Measure I

SOURCE MEASURE
V ▨ I
I ☐ V

This button toggles between the voltage source and the current source

Indicator denotes the selected source.

Step 2 — Select Sweep Function

Press the FUNCTION button to select the sweep function.

FUNCTION
DC ☐
SWEEP ▨

This button toggles between dc operation and sweep operation.

Indicator denotes the selected function.

Step 3 — Select Sweep Type

A. Press Sweep CREATE.

CREATE
▨

The currently defined sweep will be displayed.

Indicator denotes that CREATE is enabled.

B. Use SELECT to display the linear staircase sweep.

LINEAR STAIR

C. Press ENTER.

Step 4 — Enter Sweep Parameter Values

A. Use the Data Entry keypad to key in each parameter value (except for range; use SELECT buttons).

B. Press ENTER to enter each value.

Whenever a value is entered (ENTER pressed), the next parameter will be displayed.

Sweep parameter values for this test:

-06.000 V START

-07.000 V STOP

+0.1000 V STEP

00.500 SEC DELAY

+0.0000 V BIAS

BEST FIXED RANGE

While in create, the rotary knob can be used to display parameters.

STEP interpreted as an absolute value. Direction is determined by START and STOP values.

Delay allows source to settle when its level changes.

C. After the range is entered (ENTER pressed), the following message is displayed:

SAVE? ENTER/CANCEL

Pressing CANCEL will cancel parameter values just entered. The sweep will default to the previously established values.

D. Press ENTER to establish the above parameter values for this sweep.

Step 5: — Enter Compliance Value

A. Press Source COMPLIANCE.

COMPLIANCE

Indicator denotes that COMPLIANCE is enabled (compliance limit is displayed).

B. Using the keypad, key in 55mA.

A compliance limit of 55mA will protect the 400mW device from damage (7V × 55mA = 385mW).

+55E-3 AMPS

Exponent form shown. The value can instead be keyed in as +0.055 amps.

C. Press ENTER.

Pressing CANCEL will return display to the previously established compliance limit.

Step 6 — Select Remote Sense

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. Never change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

A. Press MENU and use rotary knob to display present sense selection.

B. If in local sense, press SELECT to display remote sense.

SELECT buttons toggle between local and remote sense.

REMOTE SENSE

C. Press ENTER and then MENU.

Step 7 — Select Autorange

Press AUTORANGE

This button toggles between autorange and manual range.

Indicator denotes that AUTORANGE is enabled.

With AUTORANGE enabled, the lowest possible measurement range will be used at each step of the sweep. Otherwise, all measurements would be made on the 100mA range (as set by the compliance value).

Step 8 — Perform Sweep

A. Press OPERATE

Indicator denotes that OPERATE is enabled.

The output is at the bias level (0V), but the sweep has not yet started (MANUAL Trigger indicator blinking).

B. Press MANUAL Trigger to start the sweep.

While the sweep is in progress, the MANUAL Trigger indicator stops blinking, and the voltage source steps can be observed on the display.

Step 9 — Standby

Press OPERATE to place unit in standby after sweep is completed.

Step 10 — Recall Sweep Data

A. Press Sweep RECALL	*Data for the last data point of the sweep is displayed first.* *Indicator denotes that sweep recall is enabled.*
B. Use the Rotary Knob and the SELECT buttons to display data.	*Stored data is arranged in a matrix array. In general, the knob moves the display "window" vertically in the matrix, while the buttons move the "window" horizontally.* *Figure 1-20 shows a graph of typical data for this test.*

IEEE-488 Bus Operation

The following HP BASIC 4.0 program will perform the zener diode test from over the IEEE-488 bus. This program is written for a Source Measure Unit that is set to an IEEE address of 16.

```
 10   REMOTE 716
 20   CLEAR 716
 30   DIM A$ [800]
 40   OUTPUT 716; "F0,1X"             Source V Measure I
                                      (sweep)
 50   OUTPUT 716; "Q1,–6,–7,          Lin staircase sweep
      .1,2,500X"                      parameters
 60   OUTPUT 716; "L.055,0X"          Compliance; 55mA, auto-
                                      range
 70   OUTPUT 716; "O1X"               Remote sense
 80   OUTPUT 716; "N1X"               Operate
 90   OUTPUT 716; "H0X"               Trigger start of sweep
100   OUTPUT 716; "G15,0,2X"          Output all data on talk
110   ENTER 716; A$                   Talk
120   PRINT A$                        Display all sweep data
130   END
```

NOTE: Place unit in standby when sweep is completed (MANUAL trigger light blinking).

When the program is run, the Source Measure Unit will sweep from –6V to --7V in –100mV steps. After the sweep is completed, all the sweep data will be displayed on the computer CRT.

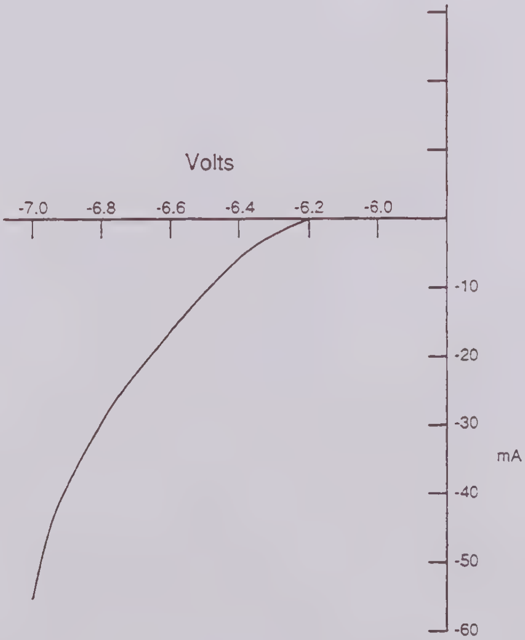


Figure 1-20. Zener Diode Breakdown

SECTION 2
Operation

2.1 INTRODUCTION
2.2 POWER UP PROCEDURE
2.2.1 Line Voltage Setting
2.2.2 Fuse Replacement
2.2.3 Power Cord
2.2.4 Power Up Display Messages and Self Test
2.2.5 Power Up Configuration
2.2.6 Line Frequency Setting
2.2.7 Warm Up Period
2.2.8 Fan Filter Cleaning

SECTION 2
Operation

2.1 INTRODUCTION

This section contains the detailed information to operate the Source Measure Unit. Generally, the information is presented in a sequence that the unit would most likely be used. Along with front panel operation, abbreviated information for using it over the IEEE-488 bus is also provided. Detailed IEEE-488 bus operation is covered in Section 3 of this manual.

The information in this section is divided into four parts: connections, operating fundamentals, sweep operation, and source-measure considerations.

2.2 **Power Up:** Provides detailed information for configuring and connecting the unit to the available line voltage.

Connections

2.3 **Basic Test Connections:** Covers the basic information for connecting a Source Measure Unit to a device under test (DUT) that is installed in a test fixture.

2.4 **Multi Unit Connections:** Connection requirements when using two or more units in a test system.

2.5 **IEEE-488 Bus Connections:** Provides the information needed for connections to the IEEE-488 bus.

2.6 **Typical Switching Configurations:** Recommends some typical switching configurations using various switching cards.

2.7 **High Voltage Switching Configurations:** Recommends high voltage switching cards for the Model 237.

Operating Fundamentals (DC Operation)

2.8 **Display Messages:** Provides a table that lists and explains display messages.

2.9 **Data Entry:** Explains how to enter data into the Source Measure Unit.

2.10 **Menu:** Contains the detailed information for using the MENU selections. These include; dc delay, default delay, sensing, ac line frequency, IEEE address, factory initialization, and self tests.

2.11 **Select Source and Function:** Provides the detailed information associated with source selection and function selection (dc or sweep).

2.12 **Set Compliance and Measurement Range:** Explains compliance and provides the detailed procedure to set compliance and measurement range.

2.13 **Autorange:** Explains the autorange (measurement) feature and how to use it.

2.14 **Operate:** Explains the operate and standby states.

2.15 ∫ Time: Explains integration time and how to select it.

2.16 Filter: Covers the averaging filter and how to use it.

2.17 Suppress: Covers the suppress feature in detail and explains how to use it.

Sweep Operation

2.18 Basic Sweep Waveforms: Describes the six available sweep waveforms.

2.19 Create Sweep List: Explains how to define sweep parameters for a selected sweep waveform.

2.20 Append Sweep: Explains how to append one or more waveforms to an existing sweep waveform.

2.21 Modify Sweep: Explains how to modify source and delay points of an existing sweep waveform. Allows custom shaped waveforms to be fabricated.

2.22 Configure Triggers: Explains how to configure the triggers that are used to start and control sweeps.

2.23 Performing a Sweep: Summarizes the fundamentals of performing a sweep.

2.24 Recalling Sweep Data: Explains how to recall test data from the sweep buffer.

2.25 Multi Unit Operation: Provides basic information required for synchronized operation of two or more Source Measure Units.

Source-Measure Considerations

2.26 Current Clamp: Explains the internal current clamp circuit which is used to protect the Source Measure Unit from external power sources.

2.27 Sink Operation: Explains operation when the Source Measure Unit is dissipating power rather than sourcing it.

2.28 Making Stable Measurements: Provides considerations and techniques for making stable measurements with single and multiple Source Measure Unit test systems. Includes effects of reactive loads on performance.

2.29 Measure Only: Covers the basics for using the Source Measure Unit as a stand alone electrometer.

2.30 Guarding: Provides basic theory on guarding.

2.31 Electrostatic Interference: Provides techniques to minimize electrostatic interference.

2.32 Thermal EMFs: Provides techniques for minimizing thermal EMFs that can adversely affect low current measurements.

2.33 Radio Frequency Interference: Explains radio frequency interference (RFI) and how to minimize its effects.

2.34 Ground Loops: Explains the adverse effects of ground loops and how to avoid them.

2.2 POWER UP PROCEDURE

2.2.1 Line Voltage Setting

The Source Measure Unit is designed to operate from 105-125V or 210-250V line power ranges. A special transformer may be installed (at factory) for 90-110V and 195-235V ranges. The operating voltage that the instrument is configured to operate at is indicated on the line voltage slide switch located on the rear panel (see Figure 2-1). The required switch positions for the available line voltages are summarized in Table 2-1. If the line voltage setting needs to be changed, proceed as follows:

Table 2-1. Line Voltage Selection (50-60Hz)

Line Voltage	Voltage Selection Switch Position
105 – 125V	115V
210 – 250V	230V
90 – 110V*	115V
195 – 235V*	230V

*Requires special power transformer, installed at the factory.

WARNING
Make sure the Model 236/237/238 is disconnected from the power line and all other equipment before proceeding.

1. Locate the line voltage switch on the rear panel (see Figure 2-1). Place the blade of a screwdriver into the slot in the switch slot and slide it over to the alternate position.
2. Install a fuse consistent with the operating voltage, as described in the next paragraph.

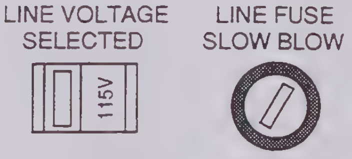


Figure 2-1. Line Voltage Switch and Line Fuse

2.2.2 Fuse Replacement

A rear panel fuse located adjacent to the line voltage switch (see Figure 2-1) protects the power line input of the Source Measure Unit. If the fuse needs to be replaced (line voltage switch setting changed or suspected blown fuse), perform the following steps:

WARNING
Make sure the Source Measure Unit is disconnected from the power line and other equipment before replacing the fuse.

1. With the power off, place the end of a flat-blade screwdriver into the slot in the rear panel line LINE FUSE holder. Push in gently and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the holder and its internal spring will push the fuse and carrier out of the holder.
2. Remove the fuse and replace it with the type recommended in Table 2-2.

CAUTION
Do not use a fuse with a higher current rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse. See the service manual for troubleshooting information.

Table 2-2. Line Fuse Selection

Model Number	Line Voltage	Fuse Type	Keithley Part No.
236, 237	90-125V	1A, 250V, 3AG, Slo Blo	FU-10
	195-250V	1/2A, 250V, 3AG, Slo Blo	FU-4
238	90-125V	1.25A, 250V, 3AG Slo Blo	FU-28
	195-250V	0.6A, 250V, 3AG, Slo Blo	FU-27

3. Install the new fuse and the fuse carrier into the holder by reversing the above procedure.

2.2.3 Power Cord

Connect the female-end of the power cord to the ac receptacle on the rear panel of the instrument. Connect the male-end of the cord to a grounded ac outlet.

WARNING
The Source Measure Unit is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in injury or death due to electric shock.

CAUTION
Be sure that the power line voltage agrees with the indicated range on rear panel line voltage switch. Failure to observe this precaution may result in instrument damage not covered by the warranty. The procedure to configure the instrument for the alternate line voltage is found in paragraph 2.2.1.

2.2.4 Power Up Display Messages and Self Test

Turn on the instrument by pressing the POWER button. During the power up cycle, the unit will perform the following:

1. The Source Measure Unit will perform tests on its memory elements. If the self tests fail, one or more error messages will be displayed and operation may be interrupted until the problem is resolved. In this event, refer to the service manual for troubleshooting information. A brief explanation of any displayed error message is contained in Table 2-3 (see paragraph 2.8).

NOTE
If the instrument is still under warranty and a problem develops, it should be returned to Keithley Instruments, Inc. for repair.

2. Assuming the unit successfully passes the self test, it will then briefly display the software revision level. For example:

   SOFTWARE REV A04

   The revision level of your unit may be different. In any case, the software revision level should be recorded in case it becomes necessary to replace the ROMs in the future.
3. Next, the programmed primary IEEE-488 address will be displayed as in the following example:

   IEEE ADDRESS 16

   At the factory, the IEEE address of the Model 236/237/238 is set to 16. If the address has been changed by the user, then that address value will instead be displayed.
4. The unit will then begin normal operation in accordance with the power up configuration discussed in the next paragraph.

2.2.5 Power Up Configuration

After the self testing and power up display messages are completed, the Source Measure Unit will initialize to specific operating conditions. This initialization is summarized in Table 2-5 (see paragraph 2.10.8). A checkmark (√) indicates that the unit will initialize to whatever was previously programmed.

The Source Measure Unit will go to the factory default conditions when the Factory Init program is run or J0 is sent over the IEEE-488 bus. Refer to paragraph 2.10.8 for details.

2.2.6 Line Frequency Setting

The instrument will operate at a line frequency of 50 or 60Hz. In order for the Source Measure Unit to operate properly for line cycle measurements, its line frequency setting must match the frequency of the power line. To check or change the line frequency setting of the instrument, perform the following steps:

1. Press the MENU button on the keypad. The MENU light will turn on and the first item on the menu, which is dc delay time, will be displayed.
2. Turn the rotary knob until the currently selected ac line frequency is displayed. For example, if the instrument is set for 60Hz operation, the following message will be displayed on the menu:

   60HZ AC LINE
3. The alternate line frequency setting can be selected by displaying it with the SELECT buttons and then pressing ENTER.

4. To exit from the menu, again press the MENU button.

NOTE

Changing the ac line frequency with a front panel menu selection also changes the integration time if LINECYCLE PERIOD is presently selected. for example, a line frequency change from 60Hz to 50Hz also changes the integration time from 16.667msec to 20msec.

2.2.7 Warm Up Period

The Source Measure Unit can be used immediately when it is first turned on. However, the unit must be allowed to warm up for one hour to achieve rated accuracy.

2.2.8 Fan Filter Cleaning

The Model 236/237/238 has an internal cooling fan to vent heat out of the instrument case. The fan has a filter to keep dirt and dust from entering the instrument case. Contamination on pc board could result in degraded performance. The fan filter must be cleaned periodically to maintain internal cleanliness and proper ventilization.

Perform the following steps to remove and clean the fan filter element:

1. Turn off the Model 236/237/238. The fan must be off in order to prevent dirt and dust from being ingested into the instrument case while removing the filter element.
2. Position the instrument such that you are facing the rear panel. The cooling fan is internally mounted to the right-hand end of the rear panel. The filter assembly is mounted to the rear panel in front of the fan intake vents.
3. Remove the two screws that secure the vented shroud of the filter assembly to the rear panel. The filter assembly will swing away from the rear panel allowing the filter element to be removed.
4. To clean the filter element, blow out the dust and dirt with pressurized air or nitrogen.
5. Reinstall the filter assembly onto the rear panel. The two hinges of the filter shroud fit into the rear panel vents. Make sure the filter element covers all the rear panel intake vents.

Connections

2.3 BASIC TEST CONNECTIONS
  2.3.1 Interlock
  2.3.2 Guarding, Shielding and Sensing
  2.3.3 Model 8006 Component Test Fixture
  2.3.4 Custom Test Fixture
2.4 MULTI UNIT CONNECTIONS
  2.4.1 Interlock Connections
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  2.4.3 Test Connections
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  2.5.3 Recommended Cables
  2.5.4 Connection Procedure
  2.5.5 Bus Limitations
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  2.7.3 Model 7070-PCA Prototype Circuit Assembly
  2.7.4 Model 7072-HV High Voltage Semiconductor Matrix Card

Connections

2.3 BASIC TEST CONNECTIONS

In order to achieve the best results, the Source Measure Unit must be used with a test fixture to house the DUT. For optimum performance, the test fixture should provide guarding, shielding and remote sensing for the DUT. Also, the test fixture should incorporate a safety interlock to prevent access to live circuitry above 42V peak.

WARNING
To prevent an electric shock, do not use test cables that expose voltage. All test cables must be completely insulated.

The following paragraphs show how to make connections to the Keithley Model 8006 test fixture. Also, information for building a custom test fixture is covered.

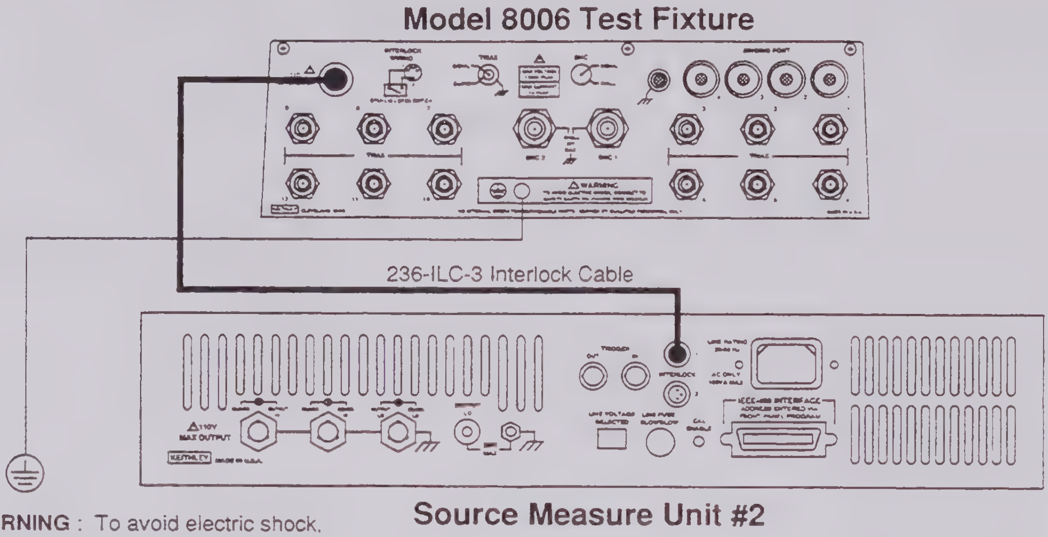
2.3.1 Interlock

The Source Measure Unit is designed to be used with a test fixture that incorporates a safety interlock switch, such as the Keithley Model 8006 test fixture. By using the Interlock feature, the Source Measure Unit cannot source a voltage or current when the lid of the test fixture is open.

The Interlock feature is automatically enabled when an interlock cable is connected to the Source Measure Unit. When using Interlock with the Model 8006 or 8007 test fixture, the Source Measure Unit will go into standby when the lid of the fixture is open or ajar. Figure 2-2 shows how the Source Measure Unit Interlock is connected to the Model 8006 test fixture. The interlock cable is shown connected to Interlock 1 receptacle of the Source Measure Unit. An interlock cable is supplied with the Models 236, 237, and 238. If a custom built test fixture is going to be used, make sure it has an interlock switch. Instructions to wire an interlock switch of a custom built test fixture to the Source Measure Unit are contained in paragraph 2.3.3.

There are two INTERLOCK receptacles on the rear panel of the Source Measure Unit. One is used to connect Interlock to a test fixture as previously explained, and the other is used to connect Interlock to a second Source Measure Unit. In this configuration, an open interlock switch at the test fixture will place both Source Measure Units in standby. Connection information for multi-unit test systems is contained in paragraph 2.4.

WARNING
When using the INTERLOCK feature in a multiple unit test system, make sure all the Model 236/237/238s remain powered up. Turning off one or more Model 236/237/238s in the test system may result in erratic INTERLOCK operation. That is, an operational Model 236/237/238 may not go into standby when the lid of the system test fixture is opened. This condition exposes the operator



WARNING : To avoid electric shock, test fixture chassis must be connected to a safety earth ground.

Figure 2-2. Interlock Connection to Model 8006

to potentially lethal voltages that could result in injury or death.

As a general rule of safety for multiple unit interlocked test systems, either keep all Model 236/237/238s powered on, or turn them all off.

WARNING

To prevent electrical shock, refer to the test fixture instruction manual for proper connection and operation procedures.

Connecting more than one test fixture to the test system defeats the purpose of Interlock. As long as one test fixture lid remains closed, the lid of another test fixture can be opened without interrupting power, thus exposing the user to potentially hazardous voltage. Special cables must be made to put the interlocks in series when using multiple fixtures.

2.3.2 Guarding, Shielding and Sensing

Guarding

The Source Measure Unit provides a driven guard for OUTPUT HI and SENSE HI. The basic guarded configurations are shown in Figure 2-3. The driven guard is always enabled and thus, always available at the rear panel of the Source Measure Unit. The guard potential (equal to the potential of OUTPUT HI) is connected to the inner shells of the triax connectors that surround OUTPUT HI and SENSE HI. Since the voltage potential on the inner shells (guard) and center conductors (OUTPUT HI and SENSE HI) are the same, virtually no leakage current can flow from OUTPUT HI or SENSE HI to low (or chassis), and the capacitance effects of the triax cable are reduced.

When the Source Measure Unit is properly connected to a test fixture (such as the 8006), guard is extended to that test fixture. Inside the test fixture, coaxial cables are used to extend the guard all the way to the DUT.

WARNING

Hazardous voltages that are present on OUTPUT HI and SENSE HI also appear on the GUARD terminals.

NOTE

Guard is not connected directly to DUT leads. A small potential difference exists that could cause erroneous readings.

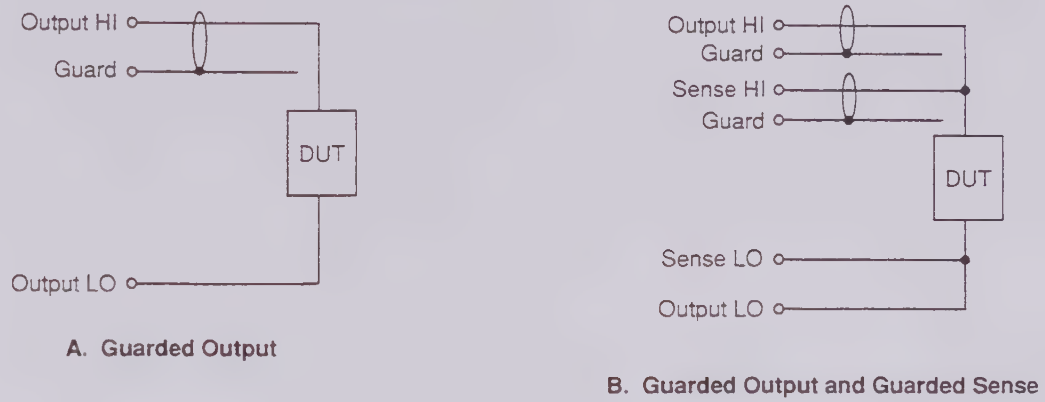


Figure 2-3. Guarded Configurations

Guard should always be used when sourcing or measuring low current. Guarded connections using the Model 8006 test fixture are covered in paragraph 2.3.3.

Additional information explaining the effects of capacitance and leakage current on Source Measure Unit speed and accuracy is covered in Source Measure Considerations.

Shielding

Shielding for the DUT must be provided. Without proper shielding, surrounding electric fields can induce noise into the test circuit resulting in erratic and noisy measurements. Optimum shielding is achieved only when the OUTPUT LO to chassis ground link on the rear panel is installed. Unless you intend to float the unit, always leave the ground link installed.

When properly connected to the Source Measure Unit, the metal chassis of the test fixture (such as the 8006) functions as a shield since it is connected to chassis ground via the outer shields of the triax cables. The inner panel of the test fixture, which is insulated from the chassis, provides additional shielding when it is connected to circuit low or the chassis. In most cases, best results are achieved by connecting the inner panel to circuit low. However, trial and error may prove that connecting the inner panel to the chassis provides better shielding. Figure 2-4 shows the basic shield configurations. Shield connections using the Model 8006 are covered in paragraph 2.3.3.

NOTE

The inner panel of the test fixture should only be used as a shield when guard is not being used. When using guard, the inner panel should be connected to the OUTPUT HI guard of the Source Measure Unit (see paragraph 2.3.3).

Sensing

Paragraph 2.10.3 explains how to select local or remote sensing. When using remote sensing, sense lines are extended to the DUT. Figure 2-5 shows basic remote sensing configurations.

When the Source Measure Unit is connected to a test fixture (such as the Model 8006), external sense lines are extended to that test fixture. Inside the test fixture, jumpers can be used to connect the external sense lines to the DUT for remote sensing.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

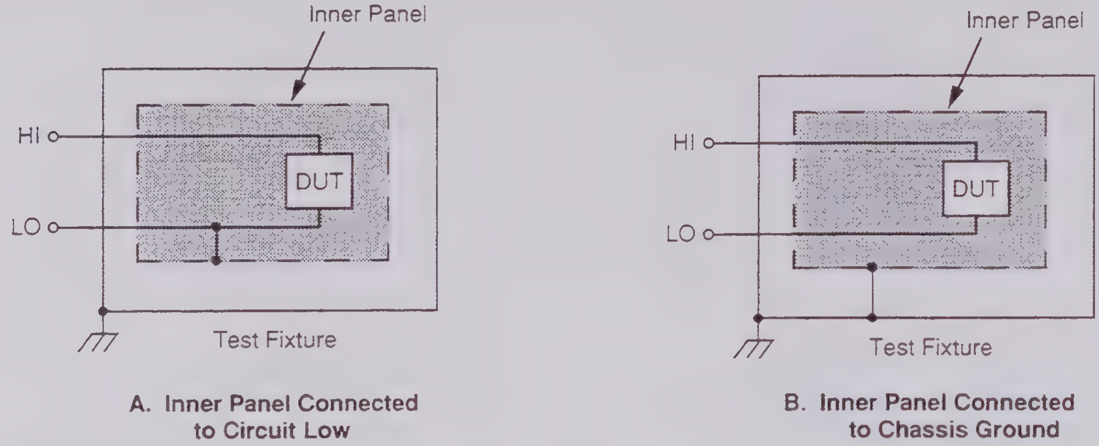

Inner Panel
HI
LO
DUT
Test Fixture
A. Inner Panel Connected to Circuit Low
Inner Panel
HI
LO
DUT
Test Fixture
B. Inner Panel Connected to Chassis Ground

Figure 2-4. Test Fixture Shielding

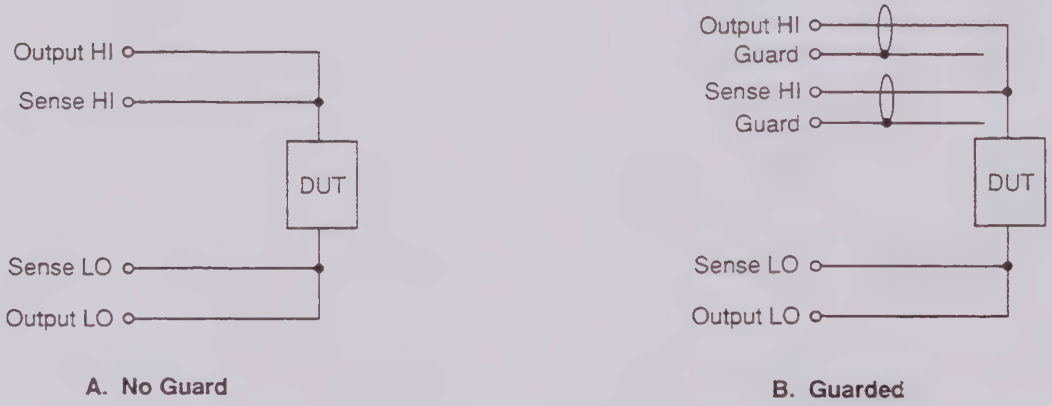

Output HI
Sense HI
DUT
Sense LO
Output LO
A. No Guard
Output HI
Guard
Sense HI
Guard
DUT
Sense LO
Output LO
B. Guarded

Figure 2-5. Remote Sensing Configuration

As a general rule, remote sensing should always be used when sourcing or measuring 1mA or more. Information on sensing is provided in paragraph 2.10.3. Remote sense connections using the Model 8006 test fixture are covered in paragraph 2.3.3.

2.3.3 Model 8006 Component Test Fixture

The Keithley Model 8006 test fixture was designed to be used with the Source Measure Unit. The Model 8006 test fixture has two axial Kelvin test clips, five radial sockets to accommodate two to 12-pin devices, and a DIP socket for IC packages with up to 28-pins. The test fixture has 12 3-lug bulkhead triax input connectors that will allow connections to up to four Source Measure Units. A connection panel and banana plug jumper cables are provided to make connections to the DUT simple.

NOTE

Detailed information for making connections to the DUT at the connection panel of the test fixture is provided in the Model 8006 Instruction Manual.

Figure 2-6A shows how the Source Measure Unit can be connected to the Model 8006 for local sensing. A 3-slot triax cable (Model 7078-TRX) is used to connect OUTPUT HI of the Source Measure Unit to the test fixture. This triax cable also extends the driven guard to the test fixture. The easiest way to connect OUTPUT LO of the

Source Measure Unit to the test fixture is to use a single conductor banana plug cable as shown. Inside the test fixture, connections to the DUT are made with mini-jack jumper cables. If the driven guard is going to be used, a guarded mini-jack jumper cable would be used to extend guard to the DUT as shown in Figure 2-6B.

Figure 2-7A shows how the Source Measure Unit is connected to the Model 8006 test fixture for remote sensing. Three 3-slot triax cables are used to route the 4-wire connections to the test fixture. The two triax cables for OUTPUT HI and SENSE HI also extend the driven guard to the test fixture. Inside the test fixture, 4-wire connections to the DUT are made with mini-jack jumper cables. If the driven guard is going to the used, two guarded mini-jack jumpers would be used to extend guard to the DUT as shown in Figure 2-7B.

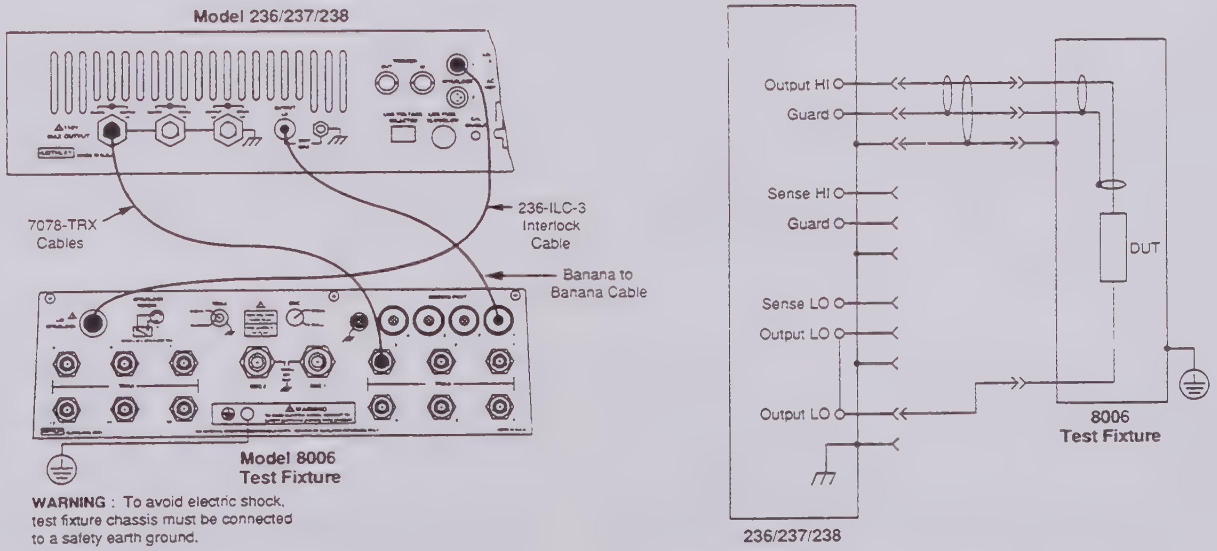
NOTE

By always connecting the three triax connectors of the Source Measure Unit to the Model 8006 test fixture, remote sense and guard will always be available at the connection panel of the test fixture.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

The two inner connection panels of the Model 8006 test fixture are insulated from the outer casing which is connected to chassis and a safety earth ground. As a general rule, when extending guard to the DUT, also connect the inner panels to the driven guard. Guarding these panels helps reduce the capacitance seen between otherwise unguarded areas and the test fixture chassis. As a result, source-measure speed at low current levels can be significantly increased. If guarding is not necessary, the panels can be connected to circuit low (or chassis) to improve shielding.

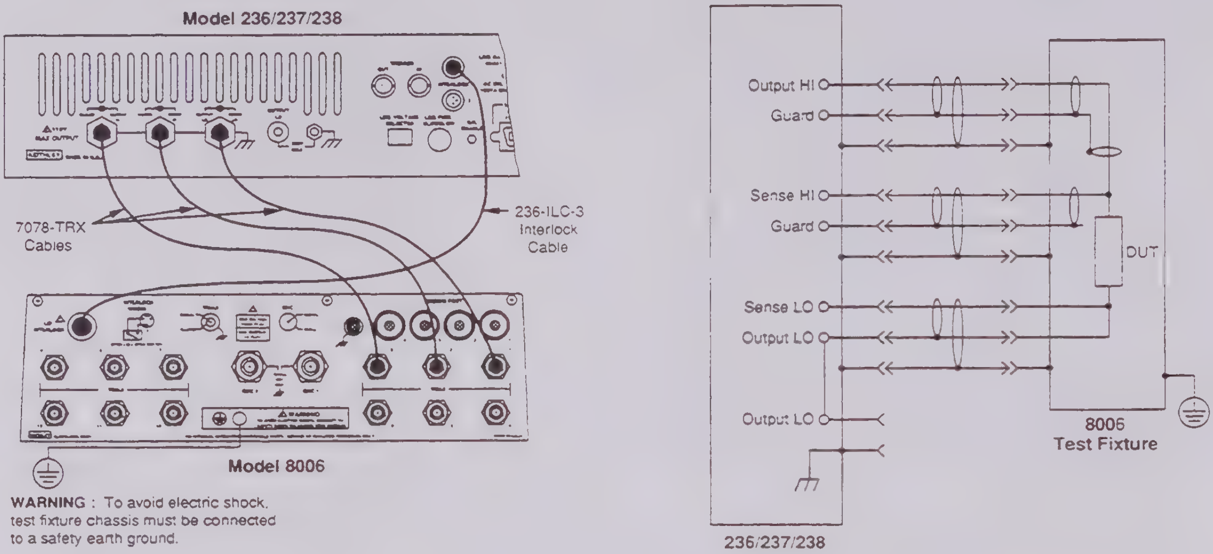


WARNING : To avoid electric shock, test fixture chassis must be connected to a safety earth ground.

A. Source Measure Unit Connections to Test Fixture

B. Connections Schematic (Guard extended to DUT)

Figure 2-6. Local Sense Connections Using Model 8006 Test Fixture



WARNING : To avoid electric shock. test fixture chassis must be connected to a safety earth ground.

A. Source Measure Unit Connections to Test Fixture

B. Connections Schematic (Guard extended to DUT)

Figure 2-7. Remote Sense Connections Using Model 8006 Test Fixture

2.3.4 Custom Test Fixture

The Model 8006 test fixture is one of the most versatile test fixtures available. The connection jumper panel makes it simple to connect one or more Source Measure Units to one of a variety of DUT test sockets. In a situation where numerous devices that are similar need to be tested (such as component evaluation), it may become necessary to build a dedicated test fixture.

A simple dedicated test fixture is shown in Figure 2-8. To keep the concepts clear, single Source Measure Unit connections to a single DUT socket are shown. Figure 2-8 is intended to illustrate the basic techniques that should be applied when building a test fixture. In reality, the test fixture may need multiple DUT sockets (wired in parallel to each other), additional input triax connectors to accommodate two or more Source Measure Units, multi pin DUT sockets, and perhaps input banana plugs to bring in additional power for packaged devices.

The following requirements, recommendations and guidelines are provided in order to build a quality test fixture that is safe to use.

Test Fixture Chassis

1. The chassis of the test fixture should be metal so that it can function as a shield for the DUT mounted inside. The chassis of the test fixture will be connected to Source Measure Unit chassis via the triax cables.
2. The test box must have a lid that closes to prevent contact with live circuitry inside.

WARNING
Safe operation requires that a safety interlock switch be used to interrupt all power sources when the test fixture lid is open or ajar (see Interlock).

3. The test fixture chassis must have a screw terminal that is used exclusively for connection to a safety earth ground.

WARNING
To provide protection from shock hazards, the test fixture chassis must be properly connected to safety earth ground. A grounding wire (18 AWG or larger) must be attached securely to the test fixture at a screw terminal

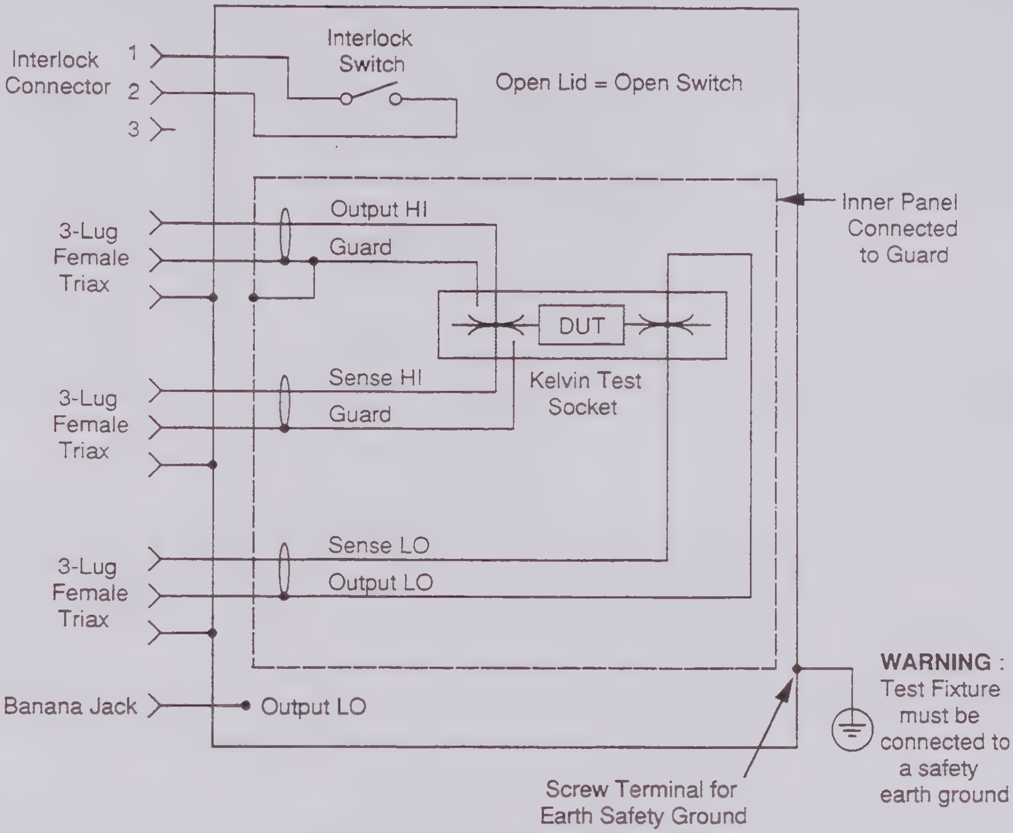

Interlock Connector
1
2
3
Interlock Switch
Open Lid = Open Switch
3-Lug Female Triax
Output HI
Guard
DUT
Kelvin Test Socket
Sense HI
Guard
3-Lug Female Triax
Sense LO
Output LO
3-Lug Female Triax
Inner Panel Connected to Guard
Banana Jack
Output LO
WARNING : Test Fixture must be connected to a safety earth ground
Screw Terminal for Earth Safety Ground

Figure 2-8. Test Fixture Using Guard and Remote Sensing

designed for safety grounding. The other end of the ground wire must then be attached to a known safety earth ground.

Inner Panel

DUT test sockets should be mounted on a metal inner panel. By insulating the inner panel from the test fixture chassis, the panel can be connected to guard as shown in Figure 2-8, or connected to output low or chassis. Connecting the inner panel to guard reduces effective capacitance between the test fixture chassis and the DUT. This reduced capacitance may provide increased source/measure speed. Connecting the inner panel to output low or test fixture chassis improves shielding from external noise (see paragraph 2.3.2).

Interlock

When a normally-open, SPST momentary switch is properly implemented as a safety interlock, the Source Measure Unit will go into standby whenever the test fixture lid is open or ajar. See paragraph 2.3.1 for information on the Source Measure Unit interlock feature.

Interlock Switch Mounting

The switch must be mounted inside the test box such that it will be closed when the lid of the test fixture is closed. Opening the lid must cause the interlock switch to open. There must never be enough clearance to allow finger access inside the box while the switch is closed. The interlock must be designed so that it cannot be defeated.

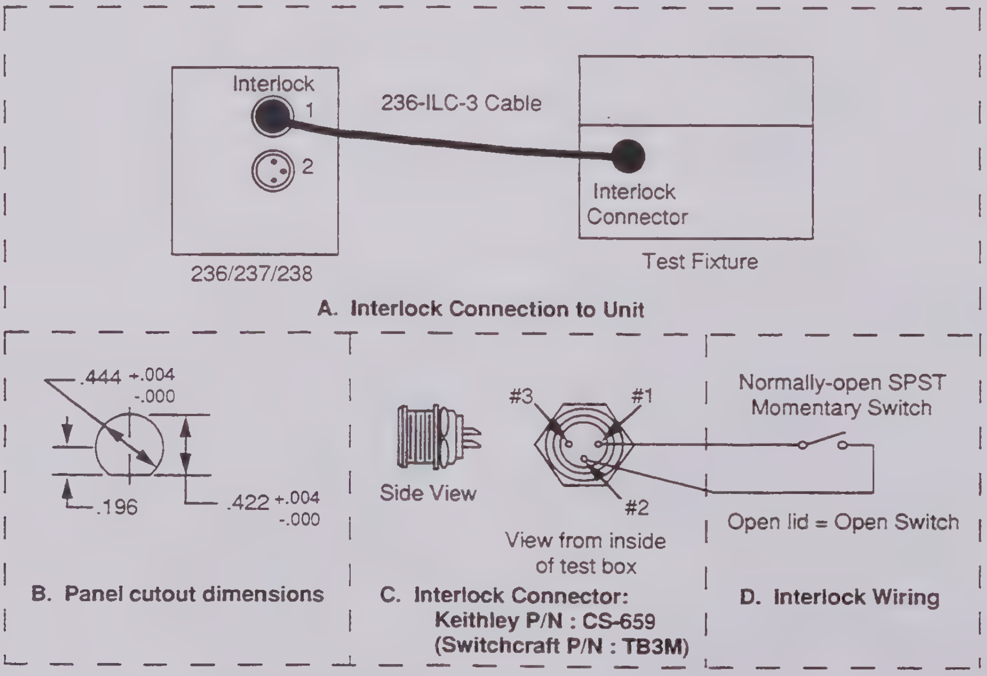
Connecting Interlock Switch to Source Measure Unit

There are a few different methods that can be used to connect the test fixture interlock switch to a Source Measure Unit and are described as follows:

236-ILC-3 Interlock Cable — By using an appropriate bulkhead connector on the test fixture, the Keithley Model 236-ILC-3 Interlock Cable can be used to connect the interlock switch to the Source Measure Unit (see Figure 2-9A). This 3-meter long interlock cable is the same one provided with the Models 8006 and 8007 test fixtures. The connector needed is shown in Figure 2-9C. Figure 2-9B shows the dimensions of the hole that must be cut into the test fixture to mount the connector. Finally, Figure 2-9D shows how to wire the connector to the test fixture interlock switch.

Modified 236-ILC-3 Interlock Cable — Interlock connections can be accomplished by using a Model 236-ILC-3 cable that has one of its plugs removed. This permits the interlock cable to be routed directly into the test fixture and hard wired to the interlock switch as shown in Figure 2-10. Note that a strain relief should be used where the cable enters the test box.

Custom Interlock Cable — A custom cable can be built to connect the test fixture interlock switch to the Source Measure Unit. Figure 2-11 provides information for building a cable that is terminated with plugs on both ends. This cable is similar to the 236-ILC-3 cable and thus, will connect to the Source Measure Unit and test fixture as shown in Figure 2-9A. If it is desired to hardwire the cable to the test fixture, leave one end of the cable unterminated and connect it to the interlock switch as shown in Figure 2-10.



A. Interlock Connection to Unit

B. Panel cutout dimensions

C. Interlock Connector: Keithley P/N : CS-659 (Switchcraft P/N : TB3M)

D. Interlock Wiring

Figure 2-9. Interlock Using Model 236-ILC-3 Cable

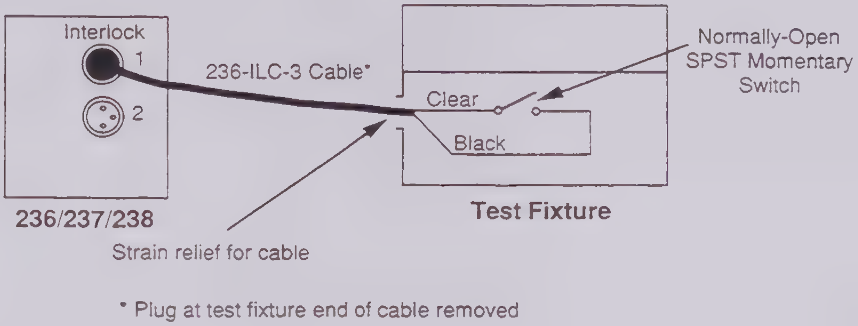
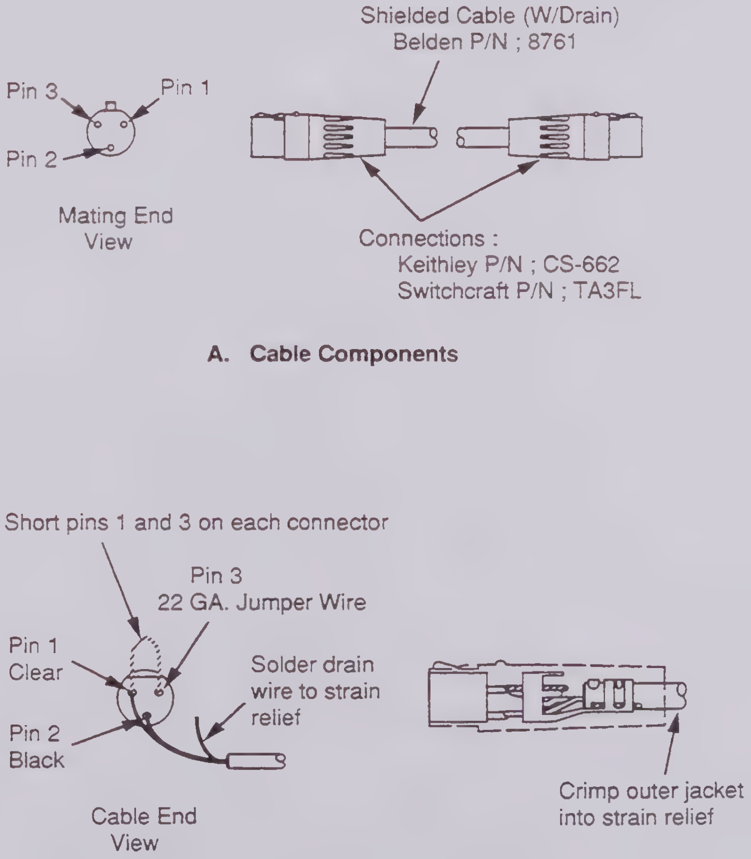

Interlock
1
2
236/237/238
236-ILC-3 Cable*
Clear
Black
Test Fixture
Normally-Open
SPST Momentary
Switch
Strain relief for cable
* Plug at test fixture end of cable removed

Figure 2-10. Modified 236-ILC-3 Interlock Cable


Shielded Cable (W/Drain)
Belden P/N ; 8761
Pin 3
Pin 1
Pin 2
Mating End View
Connections :
Keithley P/N ; CS-662
Switchcraft P/N ; TA3FL
Short pins 1 and 3 on each connector
Pin 3
22 GA. Jumper Wire
Pin 1
Clear
Pin 2
Black
Solder drain wire to strain relief
Cable End View
Crimp outer jacket into strain relief

A. Cable Components

B. Cable Connections

Figure 2-11. Custom Built Interlock Cable

Connectors, Internal Wiring and Test Sockets

The type of input connectors to use on the test fixture is, of course, influenced by the type of connectors used on other equipment. If the test fixture is going to be connected directly to the Source Measure Unit, use 3-lug triax bulkhead connectors to eliminate the need for adapters.

The outer shell of the triax connectors must be referenced to chassis ground, thus DO NOT insulate the outer shells of triax connectors from the metal chassis of the test fixture.

Inside the chassis of the test fixture you may use coaxial cables to extend guard from the OUTPUT HI and SENSE HI triax connectors to the DUT. The shields (guard) of the cables should extend as far as possible to the DUT. Ferrite beads on the cables may be necessary if the DUT is an active device (such as a bipolar transistor or MOS/GaAs Transistor).

To minimize leakage (for pA levels), only use test sockets that have excellent insulation resistance. If terminals and/or standoffs are going to be used, make sure they use virgin Teflon®.

2.4 MULTI UNIT CONNECTIONS

For many test configurations, two or more source measure units will be required. Figure 2-12 shows how a complete stand-alone (no controller) two Source Measure Unit system could be connected together. The following paragraphs cover these connections in more detail.

NOTE

For rack mounted systems, always install high power instruments at the top of the rack.

2.4.1 Interlock Connections

WARNING

To prevent electrical shock that could result in injury or death, the interlock feature of the Source Measure Unit must be used.

The interlock feature places the Source Measure Unit in standby whenever the lid of the test fixture is opened. The interlock feature is enabled when an interlock cable is connected to the Source Measure Unit. Complete information on the interlock feature is located in paragraph 2.3.1.

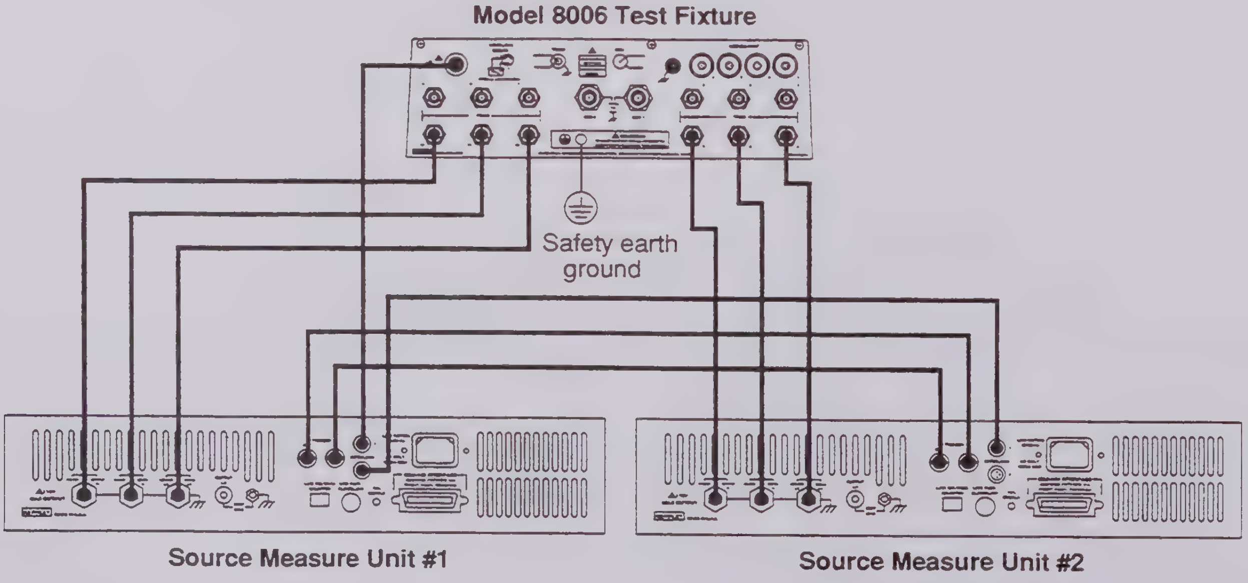


Figure 2-12. Two Source Measure Unit System

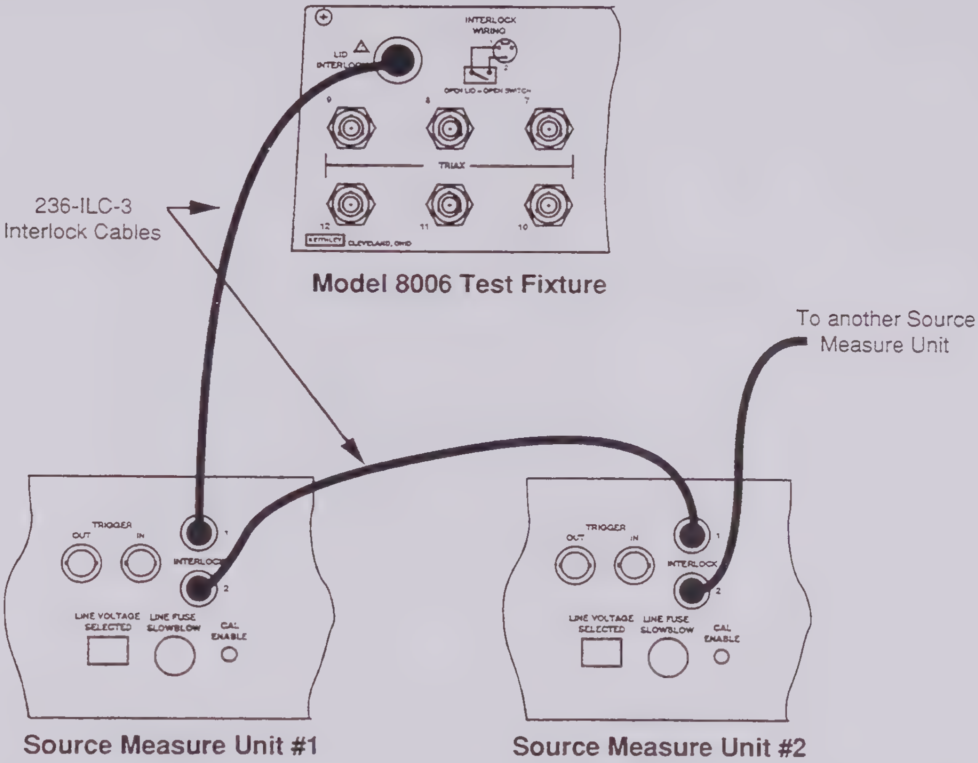

INTERLOCK WIRING
LID INTERLOCK
OPEN LID = OPEN SWITCH
1
2
9
8
7
TRIAX
12
11
10
KEITHLEY CLEVELAND, OHIO
Model 8006 Test Fixture
236-ILC-3
Interlock Cables
To another Source Measure Unit
TRIGGER
OUT
IN
INTERLOCK
LINE VOLTAGE SELECTED
LINE FUSE SLOWBLOW
CAL ENABLE
Source Measure Unit #1
Source Measure Unit #2

Figure 2-13. Interlock Connections for Multi Unit Test System

Figure 2-13 provides a more detailed drawing showing interlock connections. One interlock cable is provided with the Model 8006 test fixture. Additional interlock cables can be ordered from Keithley (Model 236-ILC-3).

In the drawing, the interlock cable from the test fixture is connected to Interlock 1 of Source Measure Unit #1. However, it could have just as well been connected to Interlock 2. The interlock connectors on the Source Measure Unit are wired identically (in parallel).

As shown in Figure 2-13, The interlock of a single test fixture is connected to one of the Source Measure Units. Interlock is then daisy-chained to the other Source Measure Units in the test system. Connecting more than one test fixture to the test system defeats the purpose of Interlock. As long as one test fixture lid remains closed, the lid of another test fixture can be opened without interrupting power, thus exposing the user to potentially hazardous voltage.

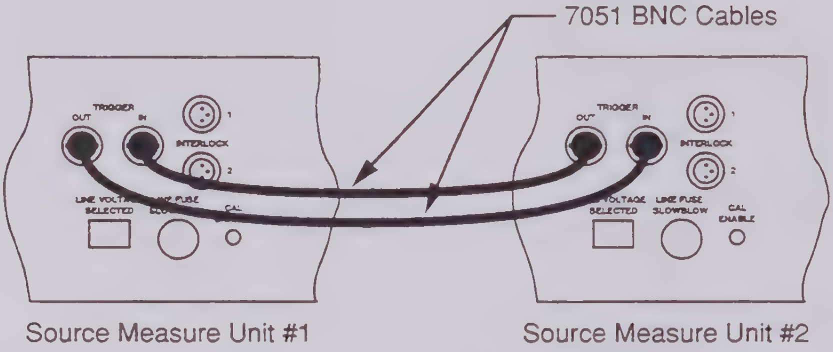
2.4.2 Trigger Connections

The Source Measure Unit can be programmed to output one or more trigger pulses. Typically, a TRIGGER OUT pulse will be sent to a second Source Measure Unit (TRIGGER IN) to start a programmed operation.

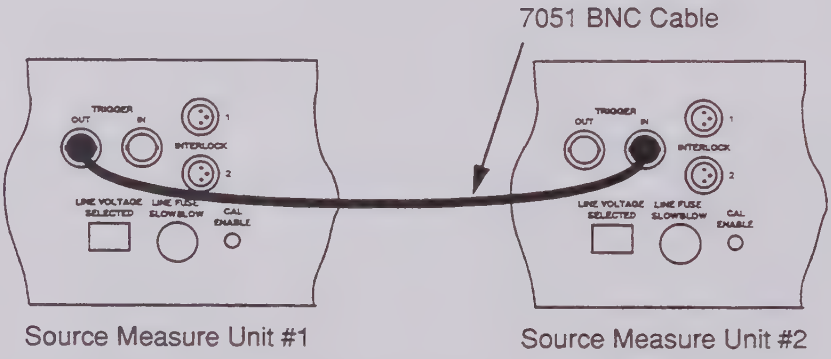
Trigger connections are shown in Figure 2-14. In the closed loop configuration, the Source Measure Units keep triggering each other until the test sweep is completed (synchronous sweep). Typically, one unit will perform the sweep steps while the other unit sets bias levels. In this configuration, a controller is not necessary. A controller becomes necessary when more than one sweep is performed by a Source Measure Unit. Since a Source Measure Unit can only store the results of only one sweep, the controller is needed to store the data so additional sweeps can be run.

The open loop configuration is typically used when a computer is being used to control the test over the IEEE-488 bus. In test configurations that use multiple sweeps, a computer is required to store the sweep data because the Source Measure Unit can only store the data of one sweep. For example, the first unit may be used to set a bias level and then trigger the second unit to perform a sweep (subordinate sweep). The computer can then store the sweep data in its own memory, and trigger the first unit to the next bias level. That unit will then trigger the second unit to perform another sweep. The computer stores that data and again triggers the start of the next sequence. This continues until the test is completed.

Multi unit operation is covered in paragraph 2.2.5.


7051 BNC Cables
TRIGGER
OUT
IN
INTERLOCK
1
2
LINE VOLTAGE SELECTED
LINE FUSE SLOWBLOW
CAL ENABLE
Source Measure Unit #1
Source Measure Unit #2

A. Closed Loop Trigger Configuration (Synchronous Sweep)


7051 BNC Cable
TRIGGER
OUT
IN
INTERLOCK
1
2
LINE VOLTAGE SELECTED
LINE FUSE SLOWBLOW
CAL ENABLE
Source Measure Unit #1
Source Measure Unit #2

B. Open Loop Trigger Configuration (Subordinate Sweep)

Figure 2-14. Trigger Connections for Multi Unit Test System

2.4.3 Test Connections

Test connections from Source Measure Units to the Model 8006 test fixture are shown in Figure 2-15. The 12 triax connectors on the test fixture are sectioned into four groups of three connectors. Each group is reserved for connection to a Source Measure Unit using 3-slot triax cables (Model 7078-TRX). Actual connections to the DUT are done at the connection panel inside the test fixture.

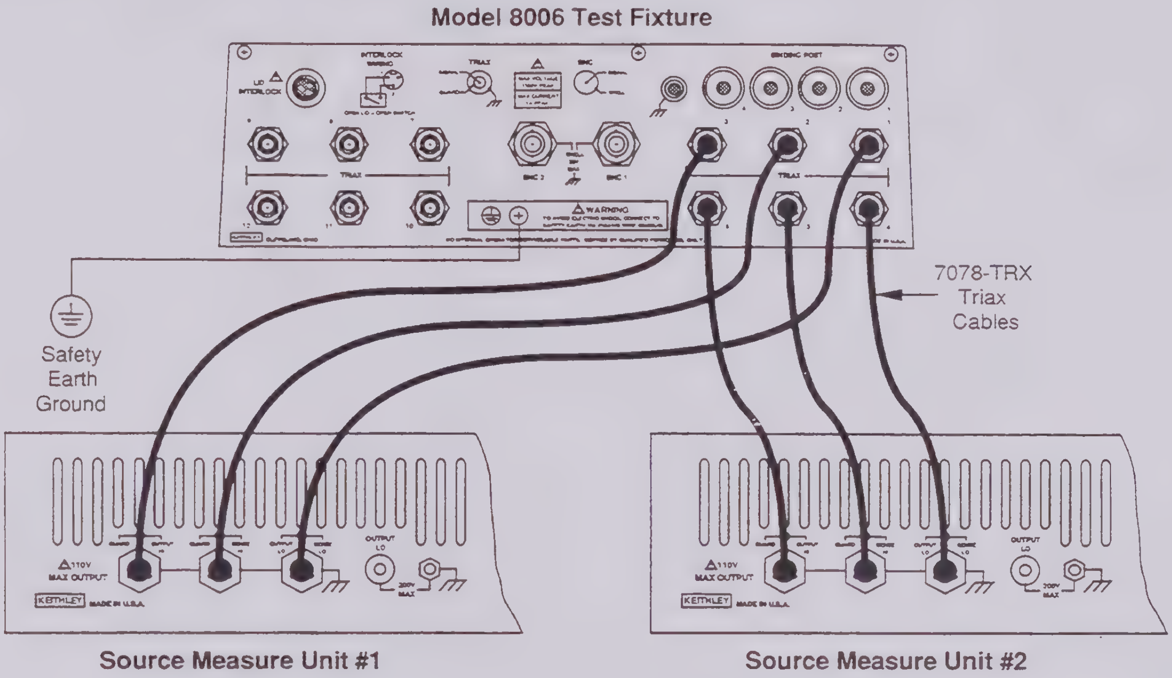

Model 8006 Test Fixture
7078-TRX Triax Cables
Safety Earth Ground
Source Measure Unit #1
Source Measure Unit #2

Figure 2-15. Test Connections for Multi Unit Test System

2.5 IEEE-488 BUS CONNECTIONS

2.5.1 Bus Connector

The Source Measure Unit can be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 2-16. The connector can be stacked to allow a number of parallel connections at one instrument. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark colored screws. Earlier versions had different screws, which were silver colored. Do not attempt to use these types of connectors on the Source Measure Unit, which is designed for metric threads.

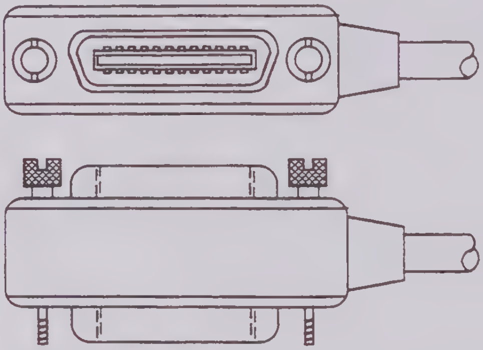


Figure 2-16. IEEE-488 Connector

2.5.2 Multiple Connections

A typical connecting scheme for a multi unit test system is shown in Figure 2-17. Although up to 14 connectors could theoretically be stacked on one instrument, it is recommended that you stack no more than three connectors on any one unit to avoid possible mechanical damage.

2.5.3 Recommended Cables

In order to minimize interference caused by electromagnetic radiation, it is recommended that only shielded IEEE-488 cables be used. The Models 7007-1 and 7007-2 shielded IEEE-488 cables are available from Keithley.

2.5.4 Connection Procedure

Connect the Source Measure Unit to the IEEE-488 bus as follows:

1. Line up the cable connector with the connector located on the rear panel of the Source Measure Unit. The connector is designed so that it will fit only one way.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make certain that the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. Consult the instruction manual for your controller for the proper connecting method.

2.5.5 Bus Limitations

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. The maximum cable length is 20-meters, or two meters times the number of devices, whichever is less. Failure to observe these limits may result in erratic bus operation.

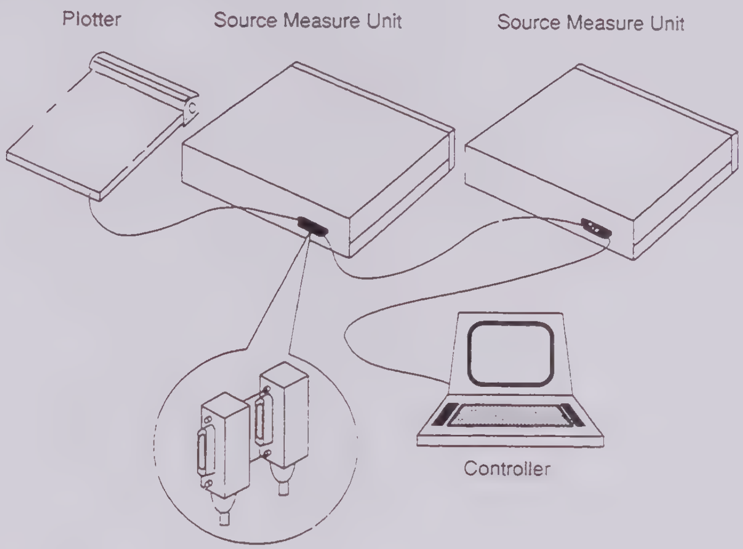


Figure 2-17. IEEE-488 Connections

2.6 TYPICAL SWITCHING CONFIGURATIONS

For multiple DUT (device under test) testing, a number of switching and matrix cards can be used with one or more Source Measure Units. The information in this paragraph explains how to connect these cards to the Source Measure Unit and a test fixture.

WARNING

When using remote sense, lethal voltage will appear at OUTPUT HI and GUARD if a sense lead is open. This voltage can cause injury or death, and damage to switching cards and DUT. Thus, ALWAYS place the Source Measure Unit in standby before changing a switch configuration.

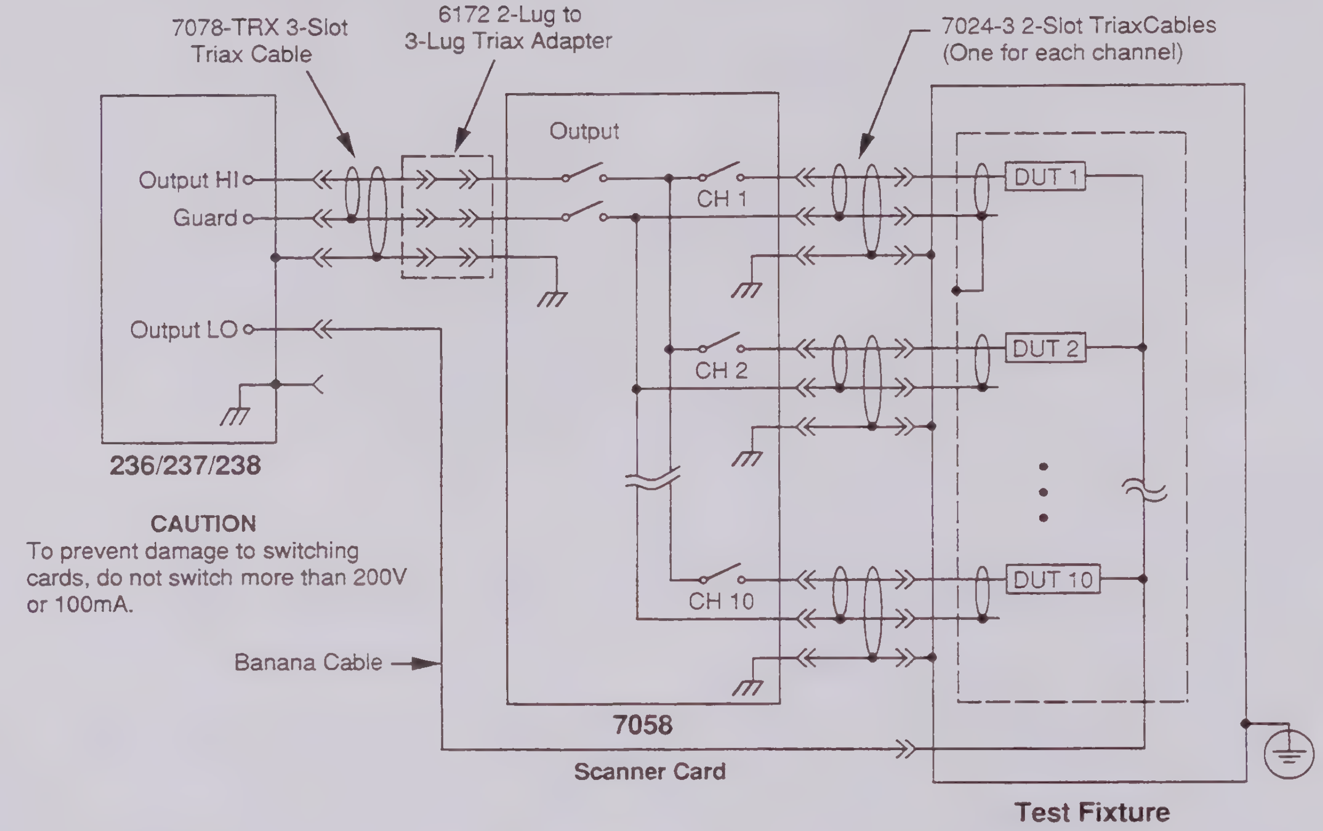
2.6.1 Model 7058 Low Current Switching Card

The Model 7058 is a 10 channel, single-pole, low current switching card (<1pA offset current) that can be controlled by a Model 705 or 706 scanner. Figure 2-18 shows an example of a single Source Measure Unit system using the Model 7058 switching card. In this configuration, Source Measure Unit OUTPUT HI is switched by the card to 10 DUTs. The Source Measure Unit is connected to one of the switching cards OUTPUT connectors (via the Model 6172 adapter) and the 10 channels of the card are connected to the test fixture. A banana plug cable is used to connect Source Measure Unit OUTPUT LO to the test fixture. However, for better shielding, the OUTPUT LO and SENSE LO triax connector on the Source Measure Unit along with a triax cable can be used to make the connection to the test fixture. Note that the switching card jumpers from signal to guard on unselected channels must be removed to keep OUTPUT HI and GUARD from shorting together.

A single Model 7058 can handle only one connector of the Source Measure Unit. More complex test systems will require additional switching cards. For example, If the test configuration is modified to utilize an additional Source Measure Unit, OUTPUT HI of the second Source Measure Unit would have to be switched by a second Model 7058 card.

Figure 2-18 shows OUTPUT LO of the Source Measure Unit connected directly to the common side of the DUTs bypassing the switching card. If it were desired to switch OUTPUT LO to increase flexibility of the test system, an additional switching card, such as the Model 7056 General Purpose Scanner Card would be required. Source Measure Unit OUTPUT LO would be connected to the second switching card.

While the first card would be used exclusively to switch OUTPUT HI, the second card would be used exclusively

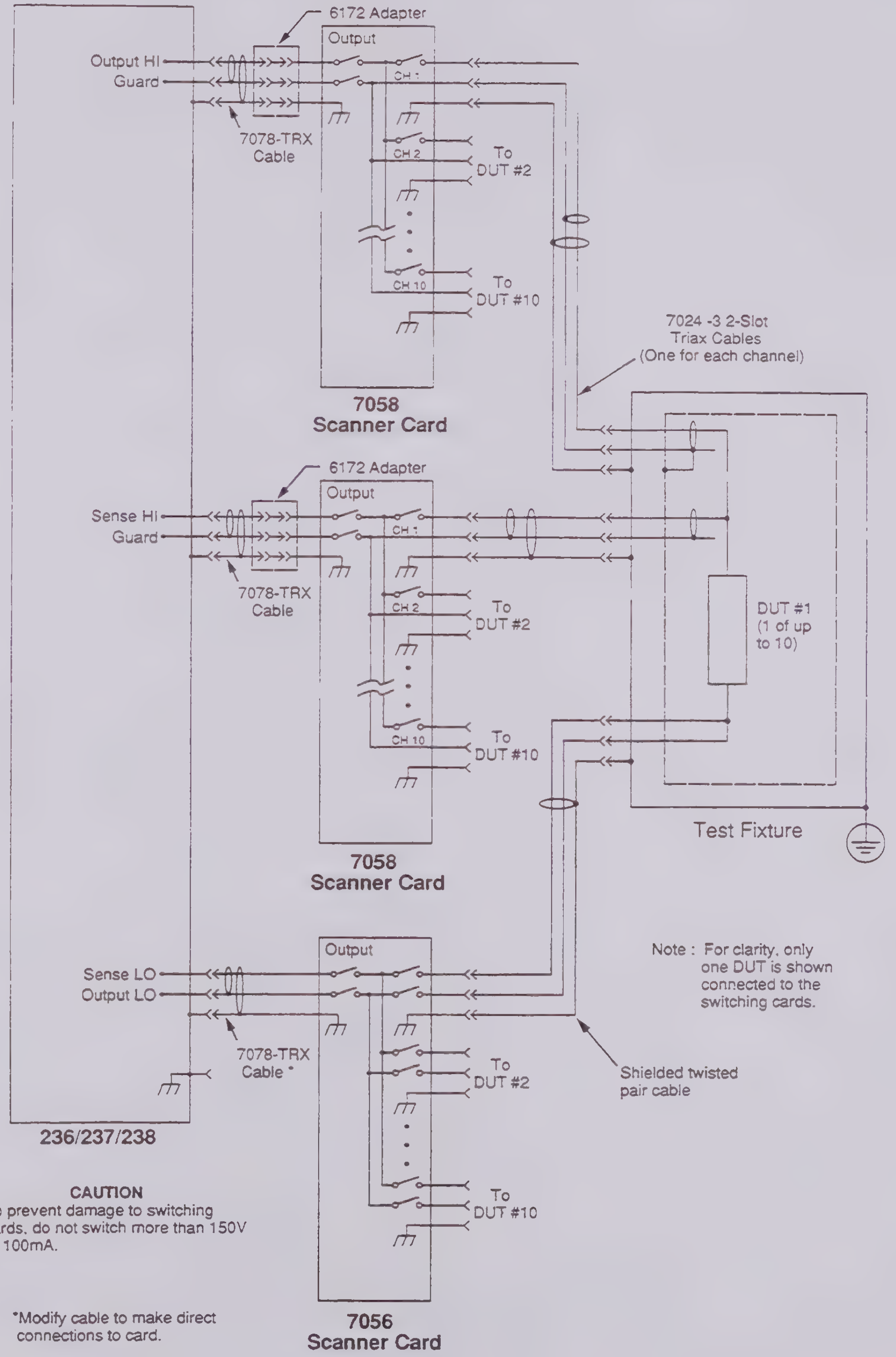

7078-TRX 3-Slot Triax Cable
6172 2-Lug to 3-Lug Triax Adapter
7024-3 2-Slot TriaxCables (One for each channel)
Output HI
Guard
Output LO
236/237/238
Output
CH 1
CH 2
CH 10
DUT 1
DUT 2
DUT 10
Banana Cable
7058
Scanner Card
Test Fixture

CAUTION
To prevent damage to switching cards, do not switch more than 200V or 100mA.

Figure 2-18. Using Model 7058 to Switch Source Measure Unit OUTPUT HI

to switch OUTPUT LO resulting in a differential (floating) switching configuration.

For remote sensing, all three triax connectors on the Source Measure Unit must be used. Thus, three switching cards would be required for a test configuration using remote sensing. An example test configuration using remote sensing is shown in Figure 2-19. Switching SENSE LO and OUTPUT LO does not require low leakage paths. Thus, a general purpose switching card (Model 7056) can be used. This test configuration will test 10 DUTs. However, for clarity, only one DUT is shown connected to the switching cards.


6172 Adapter
Output
Output HI
Guard
CH 1
7078-TRX
Cable
CH 2
To
DUT #2
CH 10
To
DUT #10
7058
Scanner Card
7024 -3 2-Slot
Triax Cables
(One for each channel)
6172 Adapter
Output
Sense HI
Guard
CH 1
7078-TRX
Cable
CH 2
To
DUT #2
DUT #1
(1 of up
to 10)
CH 10
To
DUT #10
Test Fixture
7058
Scanner Card
Output
Sense LO
Output LO
7078-TRX
Cable *
To
DUT #2
To
DUT #10
Shielded twisted
pair cable
Note : For clarity, only one DUT is shown connected to the switching cards.
236/237/238
7056
Scanner Card

CAUTION
To prevent damage to switching cards, do not switch more than 150V or 100mA.

*Modify cable to make direct connections to card.

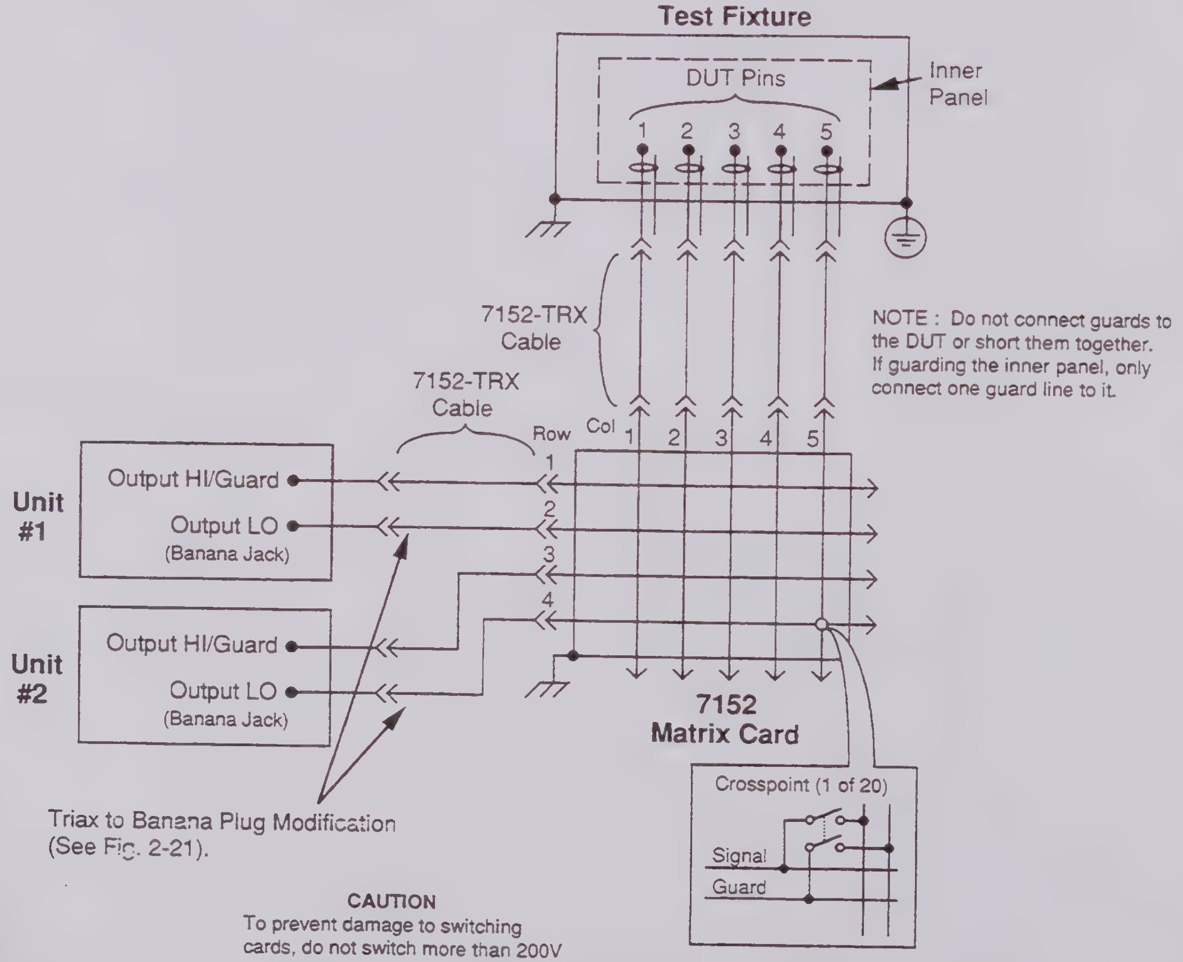
Figure 2-19. Using Model 7058 for Remote Sensing

2.6.2 Model 7152 Low Current Matrix Card

The Model 7152 is a 2-pole, 4 × 5 low current matrix card (<1pA offset current) that can be controlled by the Model 705 or 706 scanner. Figure 2-20 shows a two Source Measure Unit test configuration. In this example, OUTPUT HI and OUTPUT LO of each Source Measure Unit are independently switched, allowing maximum versatility.

This test configuration has five DUT test pins. However, additional DUT pins can be made available by adding more Model 7152 matrix cards. Each additional matrix card (row connected) can add five DUT pins to the test configuration.

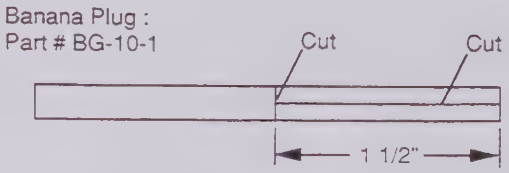
Source Measure Unit and test fixture connections to the matrix card are accomplished using Model 7152-TRX cables. These cable assemblies are terminated with 3-slot triax connectors. On each Source Measure Unit, notice that the banana jack is used to access OUTPUT LO rather than the triax connector. This allows OUTPUT LO to be routed to the signal path of the matrix. On the Source Measure Unit triax connector, OUTPUT LO is located on the inner shell which, through normal triax connections, would put OUTPUT LO on the guard path of the matrix card. Figure 2-21 shows the cable modification required to connect the OUTPUT LO banana jack to the 3-slot triax cable..


Test Fixture
DUT Pins
Inner Panel
1
2
3
4
5
7152-TRX Cable
7152-TRX Cable
Row
Col
1
2
3
4
5
1
2
3
4
Unit #1
Output HI/Guard
Output LO
(Banana Jack)
Unit #2
Output HI/Guard
Output LO
(Banana Jack)
7152 Matrix Card
Crosspoint (1 of 20)
Signal
Guard
Triax to Banana Plug Modification (See Fig. 2-21).

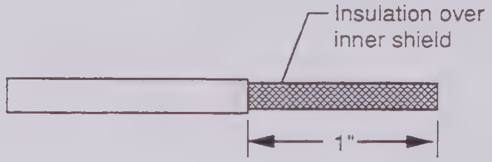
NOTE : Do not connect guards to the DUT or short them together. If guarding the inner panel, only connect one guard line to it.

CAUTION
To prevent damage to switching cards, do not switch more than 200V or 500mA. Also, incorrect crosspoint closures will short various signal or guard lines and may cause instrument or DUT failure.

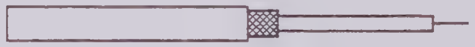
Figure 2-20. Multi Unit Connections to Model 7152



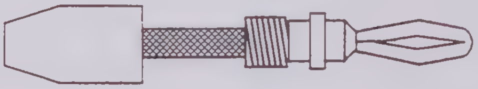
(A) Cut off insulation with knife.
Cut off outer shield.



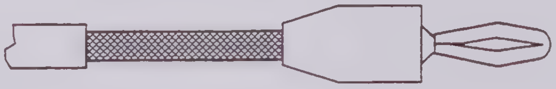
(B) Strip insulation and cut off Inner shield.



(C) Cut off inner shield then strip inner conductor.
Slip on plastic cover.



(D) Insert wire into hole and wrap around body.



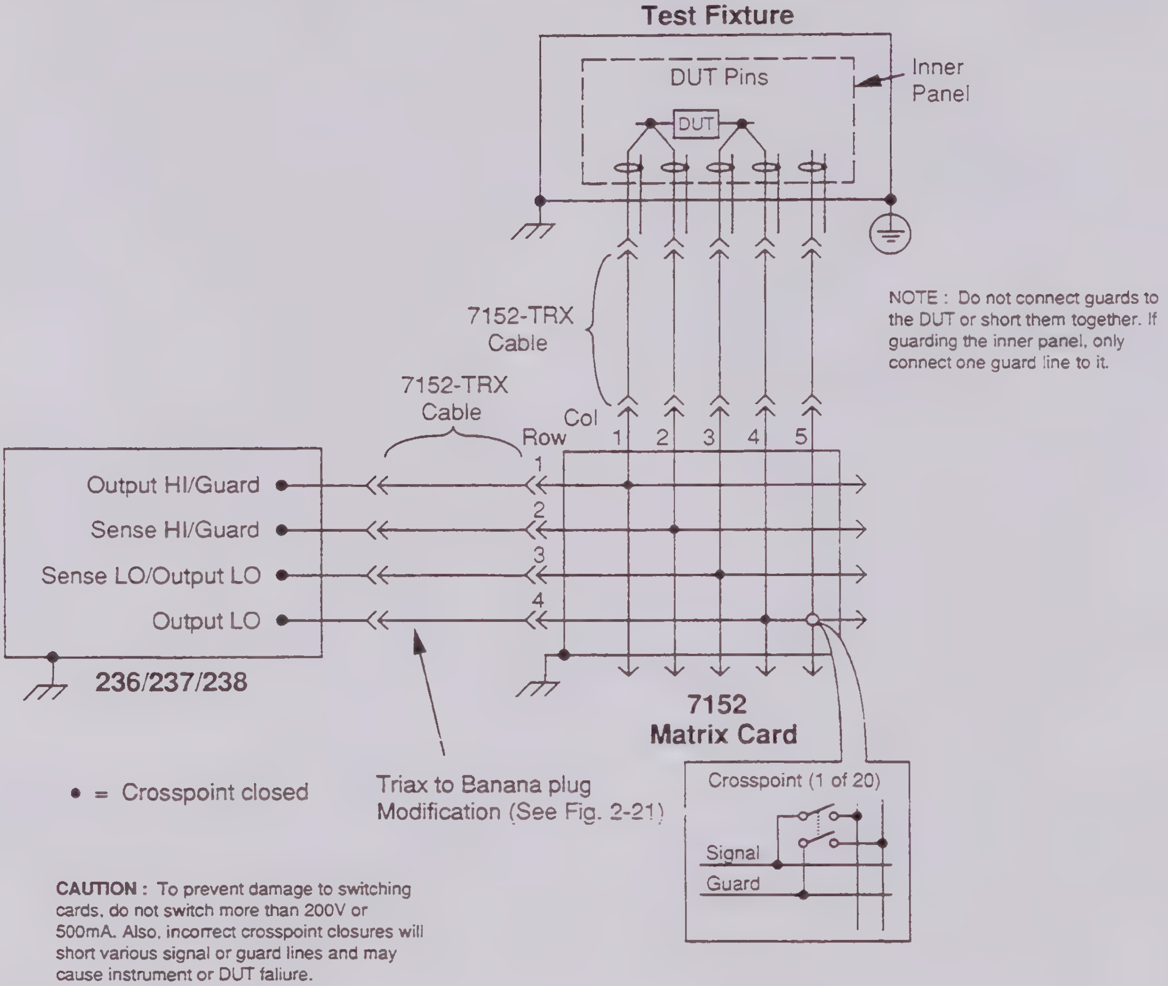
(E) Screw on plastic cover.

Figure 2-21. Triax to Banana Plug Modification

The Model 7152 matrix card can also be used by a single Source Measure Unit for remote sensing. For remote sensing, the Source Measure Unit could be connected to the matrix card as shown in Figure 2-22. OUTPUT HI/GUARD, SENSE HI/GUARD, SENSE LO and OUTPUT LO are connected to separate rows for maximum switching flexibility and optimum low current performance. Making the SENSE LO connection also connects OUTPUT LO to the matrix card through the triax connector. However, since it is connected to the inner shield, it is of no consequence as long as it is not used at the test fixture. In this test configuration, OUTPUT LO is accessed at the Source Measure Unit banana jack so that it can be independently switched.

The test configuration in Figure 2-22 "uses" four matrix rows. Remote sensing can be accomplished using three matrix rows by using OUTPUT LO at the triax connector. In this configuration, SENSE LO and OUTPUT LO use the same row. The disadvantage to this is the loss of some switching flexibility. Another option is to make OUTPUT LO a system common that is not routed (not switched) through the card. All commons are simply connected directly to the OUTPUT LO banana jack.

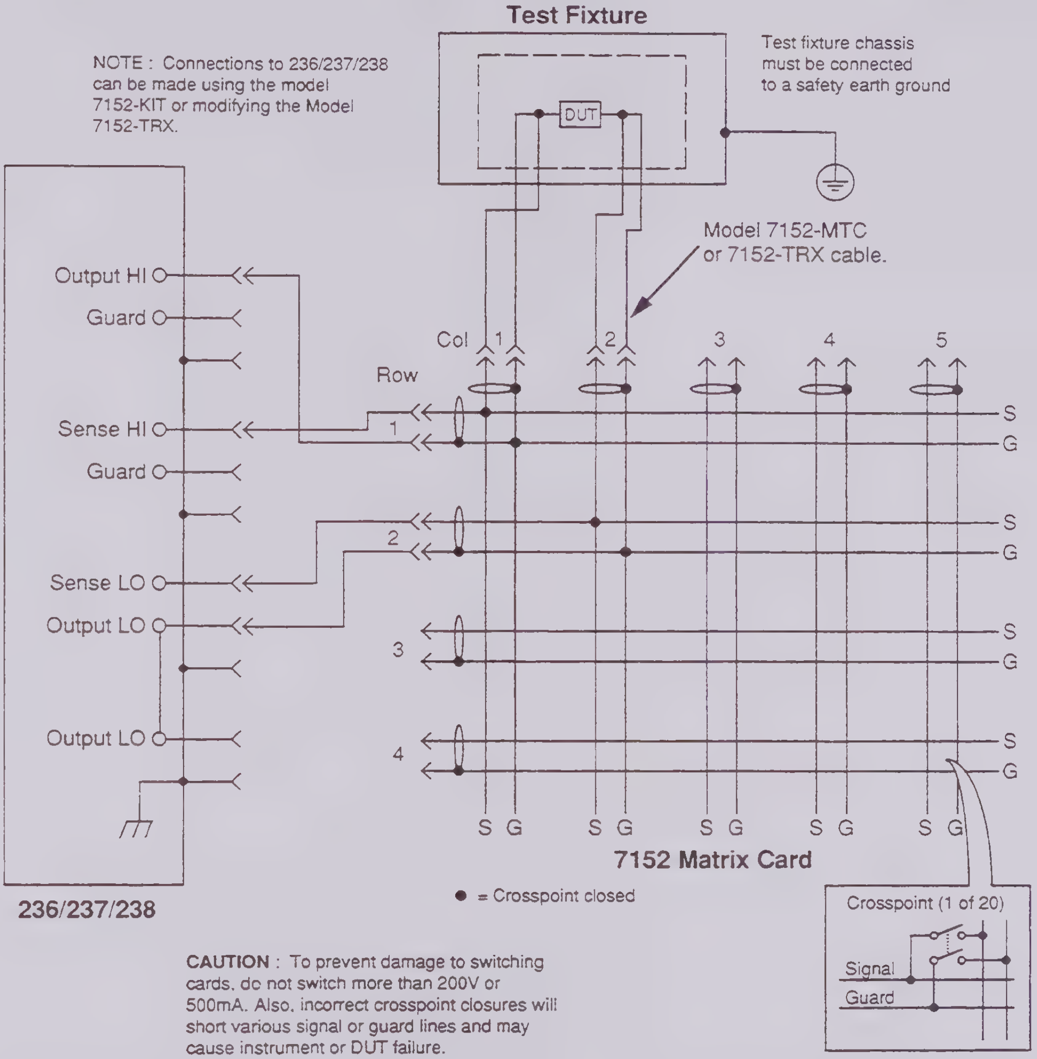
For high current applications where leakage current is not a consideration, the guard paths of the matrix card can be used for 4-wire sensing as shown in Figure 2-23. With this configuration only two matrix crosspoints are required to accomplish 4-wire connections to the DUT.


Test Fixture
DUT Pins
DUT
Inner Panel
7152-TRX Cable
7152-TRX Cable
Col
Row
1
2
3
4
5
1
2
3
4
Output HI/Guard
Sense HI/Guard
Sense LO/Output LO
Output LO
236/237/238
7152 Matrix Card
Crosspoint (1 of 20)
Signal
Guard
• = Crosspoint closed
Triax to Banana plug Modification (See Fig. 2-21)

NOTE : Do not connect guards to the DUT or short them together. If guarding the inner panel, only connect one guard line to it.

CAUTION : To prevent damage to switching cards, do not switch more than 200V or 500mA. Also, incorrect crosspoint closures will short various signal or guard lines and may cause instrument or DUT faliure.

Figure 2-22. Remote Sense and Guard Connections to Model 7152


Test Fixture
DUT
Model 7152-MTC
or 7152-TRX cable.
Output HI
Guard
Sense HI
Guard
Sense LO
Output LO
Output LO
236/237/238
Col
1
2
3
4
5
Row
1
2
3
4
S
G
S G
7152 Matrix Card
● = Crosspoint closed
Crosspoint (1 of 20)
Signal
Guard

NOTE : Connections to 236/237/238 can be made using the model 7152-KIT or modifying the Model 7152-TRX.

Test fixture chassis must be connected to a safety earth ground

CAUTION : To prevent damage to switching cards, do not switch more than 200V or 500mA. Also, incorrect crosspoint closures will short various signal or guard lines and may cause instrument or DUT failure.

Figure 2-23. Remote Sense Connections Using Model 7152 (No Guard)

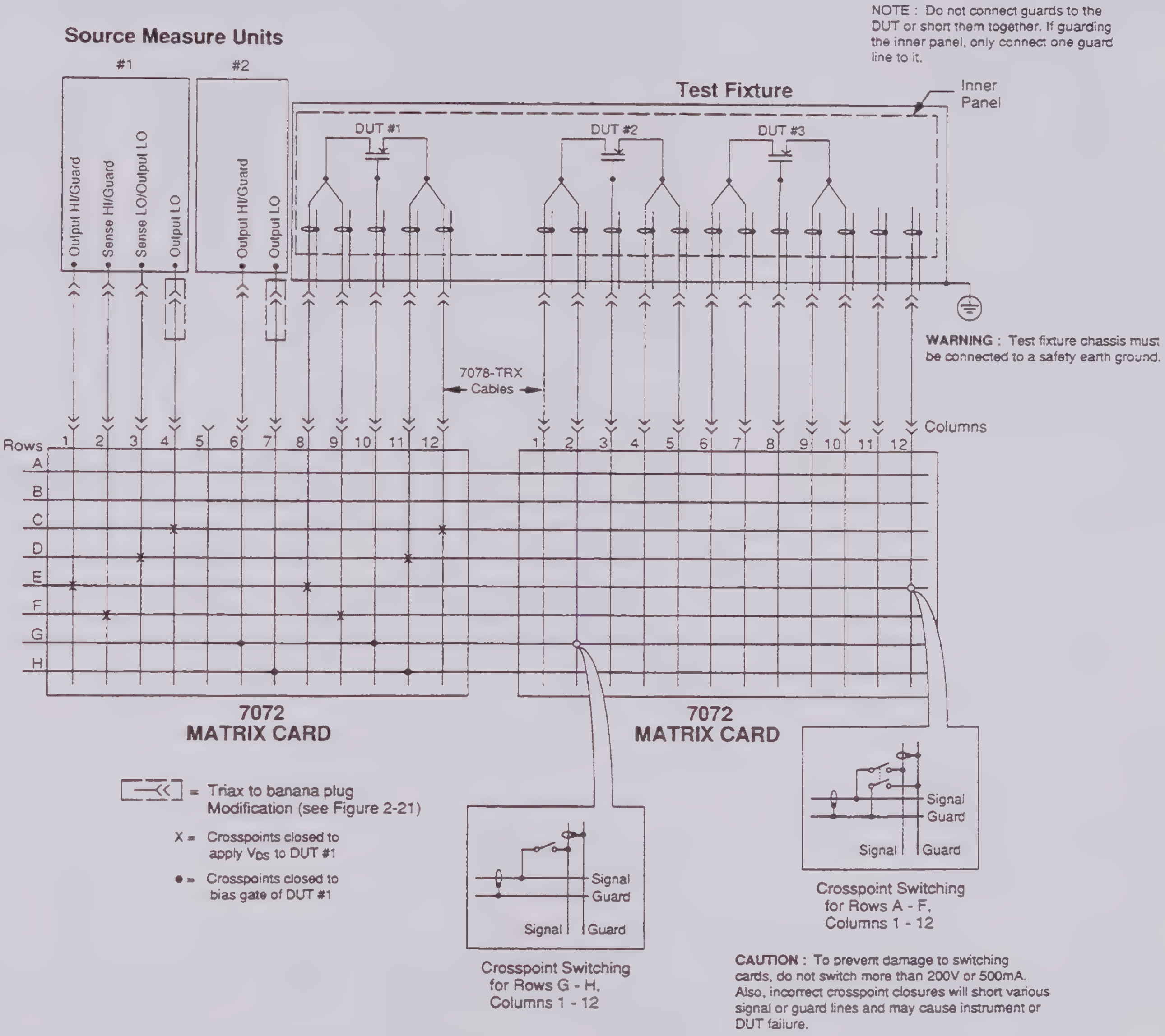
2.6.3 Model 7072 Semiconductor Matrix Card

The Model 7072 is an 8 × 12 matrix card that is controlled by the Model 707 Switching Matrix. Figure 2-24 shows a two Source Measure Unit test system using two Model 7072 matrix cards. If more DUT pins are needed, the system is easily expanded by adding more Model 7072 matrix cards. Each additional matrix card will add 12 columns to the test system.

Rows A and B of the matrix cards, which have low-current offset (<1pA), can be used for low current sourcing or measurement applications. Rows C, D, E and F are general purpose paths for situations that do not require low-current performance. Rows G and H provide single-pole switching. One of these rows could be used as a common low, while the second one could be used to source a low impedance (not sensitive) bias voltage to the DUT.

At the test fixture, the drain and source leads of the FETs are connected in a 4-wire sensing configuration. This connection scheme allows Source Measure Unit #1 to use remote sensing to accurately apply V_{DS} to the FETs. Source Measure Unit #2 uses local sense and is used to supply the bias to the gates of the FETs. Since the gates are low current, remote sensing is not necessary.

Source Measure Unit and test fixture connections to the matrix card are accomplished using Model 7078-TRX cables. These are 3-slot triax cables. On each Source Measure Unit, the banana jack is used to access OUTPUT LO. By using the adapters shown in Figure 2-21, the OUTPUT LO banana jack can be mated to a 3-slot triax cable (7078-TRX). This allows OUTPUT LO to be applied to a signal pathway and independently switched. The guard pathways of the matrix cards are used exclusively to extend the driven guards of the Source Measure Units to the DUT to eliminate the effects of leakage current.


Source Measure Units
#1
#2
Output HI/Guard
Sense HI/Guard
Sense LO/Output LO
Output LO
Output HI/Guard
Output LO
Test Fixture
Inner Panel
DUT #1
DUT #2
DUT #3
7078-TRX Cables
Rows
A
B
C
D
E
F
G
H
1
2
3
4
5
6
7
8
9
10
11
12
Columns
7072 MATRIX CARD
7072 MATRIX CARD
Signal
Guard
Signal
Guard
Crosspoint Switching for Rows G - H, Columns 1 - 12
Signal
Guard
Signal
Guard
Crosspoint Switching for Rows A - F, Columns 1 - 12

NOTE : Do not connect guards to the DUT or short them together. If guarding the inner panel, only connect one guard line to it.

WARNING : Test fixture chassis must be connected to a safety earth ground.

= Triax to banana plug Modification (see Figure 2-21)

X = Crosspoints closed to apply V_{DS} to DUT #1

● = Crosspoints closed to bias gate of DUT #1

CAUTION : To prevent damage to switching cards, do not switch more than 200V or 500mA. Also, incorrect crosspoint closures will short various signal or guard lines and may cause instrument or DUT failure.

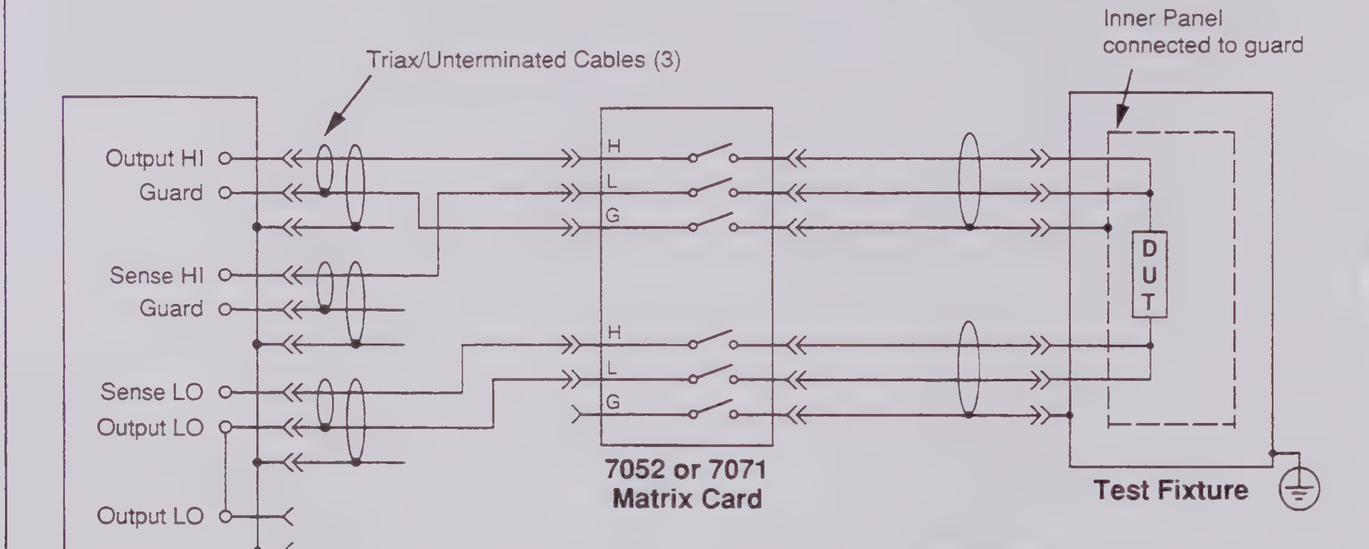
Figure 2-24. Multi Unit Test System Using Model 7072's

2.6.4 General Purpose Matrix Cards

The Models 7052 and 7071 general purpose matrix cards can be used with the Source Measure Unit for applications requiring 4-wire connections to DUT, but do not require low-current performance.

The Model 7052 is a 4 × 5 matrix that is controlled by a Model 705 or 706 Scanner. The Model 7071 is an 8 × 12 matrix that is controlled by the Model 707 Switching Matrix. Both cards have 3-pole switching and accommodate connections with screw terminals. Connections to the Model 7071 can also be made using the 38-pin mass terminated connections.

Figure 2-25 shows how these cards can be connected to the Source Measure Unit and a test fixture for remote sensing. Connections to the Source Measure Unit require three triax cables that are unterminated on one end. The appropriate conductors at the unterminated end of the cables are connected directly to the screw terminals of the matrix card. Keep in mind that the triax connectors on the Source Measure Unit are 3-lug, requiring 3-slot triax cables such as the Model 7078-TRX cables. Note that cutting one triax cable in half results in two cables that are unterminated at one end.


Triax/Unterminated Cables (3)
Inner Panel connected to guard
Output HI
Guard
Sense HI
Guard
Sense LO
Output LO
Output LO
236/237/238
H
L
G
H
L
G
7052 or 7071 Matrix Card
D U T
Test Fixture

CAUTION
To prevent damage to switching cards, do not switch more than 200V or 200mA. Also, incorrect crosspoint closures will short various signal or guard lines and may cause instrument or DUT failure.

WARNING : To avoid electric shock, the test fixture chassis must be connected to a safety earth ground.

Figure 2-25. Remote Sense Configuration Using Model 7052 and 7071 (Guarded)

2.7 HIGH VOLTAGE SWITCHING CONFIGURATIONS

There are four switching cards available from Keithley that can handle high voltages (>200V) from the Model 237 Source Measure Unit:

- Model 7154 2-pole High Voltage Scanner Card
- Model 7054 1-pole High Voltage Scanner Card
- Model 7070-PCA Prototype Circuit Assembly
- Model 7072-HV High Voltage Semiconductor Matrix Card

2.7.1 Model 7154 2-pole High Voltage Scanner Card

The Model 7154 is a 10-channel scanner card that can switch up to 1100V. It can be controlled by the Model 705 or 706 Scanner. The card uses 2-pole switching and accommodates connections with screw terminals.

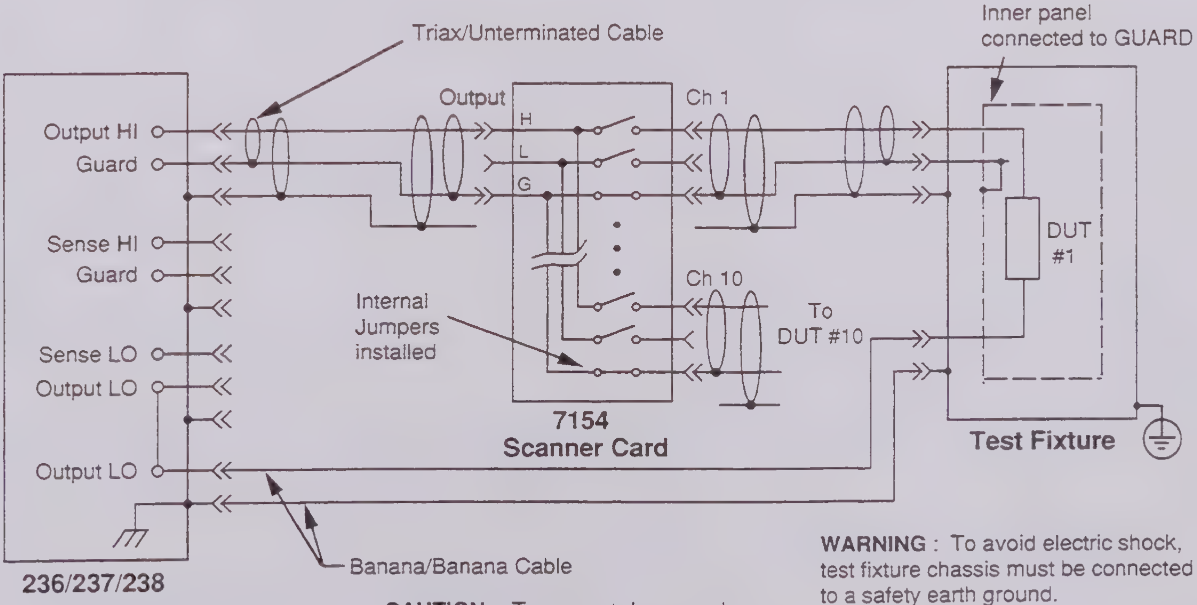
Figure 2-26 shows how this card can be used to switch OUTPUT HI to test up to 10 DUTs. Notice that the guard jumpers on the scanner card are installed, allowing the guard (G) circuit of the card to be used.

Connections to the Source Measure Unit requires a triax cable that is unterminated on one end. The appropriate conductors at the unterminated end of the cable are connected directly to the screw terminals of the scanner card. Keep in mind that the triax connectors on the Source Measure Unit are 3-lug, requiring 3-slot triax cables such as the Model 7078-TRX cables. Note that cutting one triax cable in half results in two cables that are unterminated at one end.

Figure 2-27 shows how two Model 7154 cards can be connected to the Source Measure Unit and test fixture for remote sensing. As shown in the illustration, guard can be used but special connections and precautions are needed to extend the guard to the test fixture. The special cable can be a triax cable that is unterminated on both ends. One end is wired directly to the screw terminals of the scanner card. High (H) and low (L) at the other end of the cable can be terminated with banana plugs that will mate to banana jacks mounted on the test fixture. The outer shield of the cable, which is guard, should extend as far as possible to the test fixture.

WARNING

To prevent electric shock (up to 1100V), make sure that the guard path of specially built cables is completely insulated.



CAUTION : To prevent damage, do not "hot" switch high voltage (>200V).

WARNING : To avoid electric shock, test fixture chassis must be connected to a safety earth ground.

Figure 2-26. Using Model 7154 to Switch OUTPUT HI (Guarded)

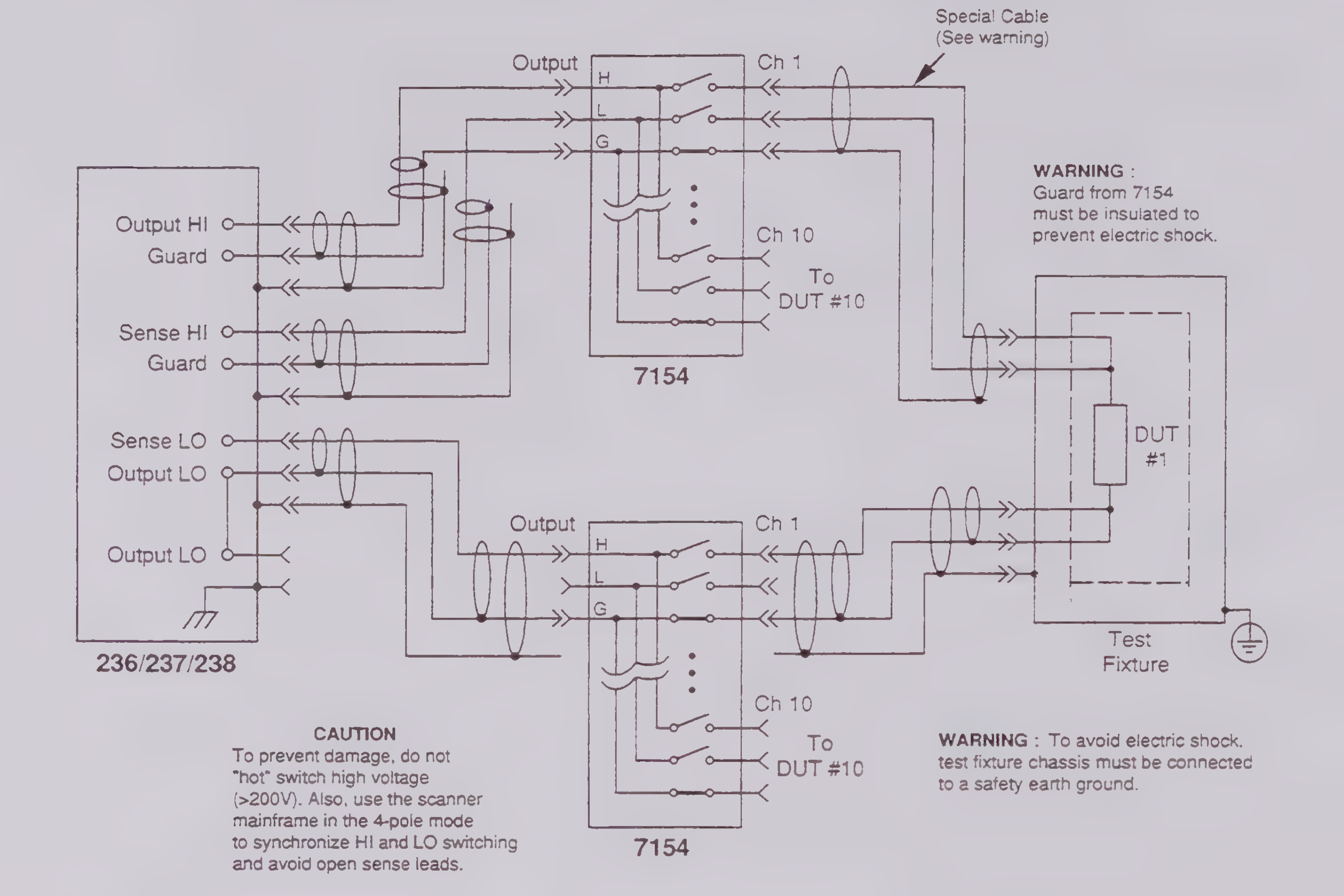

Special Cable
(See warning)
Output
H
L
G
Ch 1
Ch 10
To
DUT #10
7154
WARNING :
Guard from 7154
must be insulated to
prevent electric shock.
Output HI
Guard
Sense HI
Guard
Sense LO
Output LO
Output LO
236/237/238
DUT
#1
Output
H
L
G
Ch 1
Ch 10
To
DUT #10
7154
Test
Fixture
CAUTION
To prevent damage, do not
"hot" switch high voltage
(>200V). Also, use the scanner
mainframe in the 4-pole mode
to synchronize HI and LO switching
and avoid open sense leads.
WARNING : To avoid electric shock,
test fixture chassis must be connected
to a safety earth ground.

Figure 2-27. Using Two Model 7154s for Remote Sensing (Guarded)

2.7.2 Model 7054 1-pole High Voltage Scanner Card

The Model 7054 is a 1-pole, 10-channel high voltage scanner card that is controlled by the Model 705 or 706 Scanner. The LO path of the scanner card is not switched and is common to all 10 channels and the output. The maximum rated voltage from LO to chassis ground is 200V. As a result, GUARD of the Model 237 must never be connected to scanner card LO for high voltage switching.

2.7.3 Model 7070-PCA Prototype Circuit Assembly

The Model 7070-PCA is a prototype board that is controlled by the Model 707 Switching Matrix. An unplated prototype breadboard area is available for building high voltage switching circuits.

Ninety-six open-collector drivers are provided to control user-supplied relays. Also provided are 20 quick-disconnect terminal blocks. Each terminal block has three screw terminals.

2.7.4 Model 7072-HV High Voltage Semiconductor Matrix Card

The Model 7072-HV is an 8 × 12 matrix card that is controlled by the Model 707 Switching Matrix. It is similar to the Model 7072 Semiconductor Matrix Card except that it can switch up to 1300V on its low current rows (A and B).

Model 7072-HV row connections for high voltage switching of OUTPUT HI/GUARD and SENSE HI/GUARD signals are limited to rows A and B. Column connections are the same as those shown in Figure 2-24 for a Model 7072, except that only crosspoints in rows A and B can be used to switch high voltages.

Operating Fundamentals (Dc Operation)

2.8 DISPLAY MESSAGES
2.9 DATA ENTRY
2.9.1 Entering Source and Compliance Values
2.9.2 Entering Other Operating Parameters
2.10 MENU
2.10.1 Dc Delay
2.10.2 Default Delay
2.10.3 Sense
2.10.4 Ac Line Frequency
2.10.5 IEEE-488 Bus Address
2.10.6 Display Test
2.10.7 Memory Test
2.10.8 Factory Initialization
2.11 SELECT SOURCE AND FUNCTION
2.12 SET COMPLIANCE AND MEASUREMENT RANGE
2.13 AUTORANGE
2.14 OPERATE
2.15 ∫ TIME
2.16 FILTER
2.17 SUPPRESS

Operating Fundamentals (Dc Operation)

Operation Overview

Preliminary information explains the various display messages that may be encountered (Table 2-3) and provides the details for entering data into the Source Measure Unit from the front panel (paragraph 2.9).

The fundamental steps for basic dc operation are as follows:

1. Configure MENU items (paragraph 2.10). MENU is used to set dc delay, default delay, sensing, ac line frequency and the IEEE-488 interface address.
2. Select source and function. Paragraph 2.11 covers selection of the source (Source I Measure V or Source V Measure I) and function (dc operation or sweep operation).
3. Set compliance and measurement range as described in paragraph 2.12.
4. Enable AUTORANGE if it is to be used. AUTORANGE is used for measurements and is covered in paragraph 2.13.
5. Place the Source Measure Unit in OPERATE and, if needed, provide a trigger stimulus to apply the source to the output (paragraph 2.14).

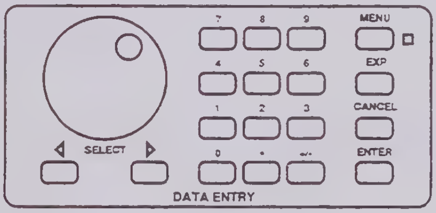
Other features that can be used include control of integration time (paragraph 2.15), filter (paragraph 2.16) and suppress (paragraph 2.17).

2.8 DISPLAY MESSAGES

The various display messages associated with instrument operation are listed in Table 2-3.

Pressing a front panel button will remove the existing error or warning message and any pending messages. If no buttons are pressed, the message is displayed for 0.8sec.

2.9 DATA ENTRY



Data Entry controls are used to enter source and compliance values. Also, they are used to select menu items (such as filter, integration time, create, setup, menu, etc.) and enter their respective parameters.

Table 2-3. Display Messages

Message	Description
BUFFER FILLED	Number of generated sweep points exceeds the buffer capacity.
CAL CONSTANTS ERR	Power-up verification of cal constants finds one or more values outside of predetermined limits; default value(s) used for values out of limits.
CAL INVALID ERR	One or more cal errors present on power-up, DCL, or SDC.
DPRAM LINK ERR	Communication error in the dual port RAM between the I/O controller and source/measure controller. Unit is not functional.
DPRAM LOCKUP	ROM or RAM failure in source/measure controller so it is not responding to I/O controller. Unit is not functional.
GENERATING SWEEP	Unit is creating or appending a sweep from the front panel.
IDDC	Unit received an illegal device-dependent command.
IDDCO	Unit received an illegal device-dependent command option.
ILLEGAL MEAS RANGE	Selected measure range is incompatible with source (V or I) or unit (236, 237 or 238).
ILLEGAL SRC RANGE	Selected source range is incompatible with source (V or I) or unit (236, 237 or 238).
INTERLOCK PRESENT	Attempted to go into operate with an interlock condition present, or an interlock condition exists while in operate.
INVALID SWEEP MIX	Cannot create/append different sweep types (pulsed and non-pulsed) in buffer.
IOU CAL CHCKSUM	Power-up checksum test of cal constants failed.
IOU DPRAM FAILED	Dual port RAM in I/O controller failed. Unit is not functional.
IOU EEROM FAILED	Electrically erasable ROM in IOU controller failed. Unit is not functional.
LOG CANNOT CROSS 0	Cannot create/append a log sweep that passes through zero.
MEAS RANGE CHANGED	Cannot have source and measure ranges of 1100V and 100mA (237), or 110V and 1A (238), at same time; measurement range lowered.
MUST CREATE SWEEP	Attempted to append, modify, or trigger a non-existent sweep.
NO AUTO IN PULSE	Cannot select source autoranging with a pulse sweep create or append.
NOT IN REMOTE	Sent an X command when the unit was not in remote (REN is false).
OFLO	An external power source has overloaded the measurement hardware in the Model 236/237/238.
PENDING TRIGGER	Waiting to finish previous operation before processing trigger.
PULSE TIME NOT MET	Specified pulse times (t_{ON} and t_{OFF}) cannot be met and will be extended.
TRIGGER OVERRUN	Unit was triggered while still processing a previous trigger; trigger is ignored.
UNCALIBRATED	No cal constants are stored in EEPROM (Source/Measure LED blinks).
VALUE OUT OF RANGE	Selected source value exceeds source range, or selected compliance value exceeds measurement range, or incremental source values are too small for selected range.
65.000 SECONDS MAX	Cannot have a dc or sweep delay greater than 65.000 seconds. Value defaults to 65.000 seconds.
1F	Power-up or memory test of IOU RAM failed. Unit is not functional.
2F	Power-up or memory test of IOU ROM failed. Unit is not functional.

2.9.1 Entering Source and Compliance Values

There are two methods to enter source and compliance values: the Adjust and the Edit method. The Adjust method uses the rotary knob to increment or decrement displayed values. With the Edit method, the value is entered using the keypad.

The Adjust method is more convenient to use when making minor "adjustments" to a displayed value. The Edit method is probably preferred when entering a completely new value.

Adjust Method

In general, the Adjust method consists of placing the cursor (blinking digit) on the digit to be changed using the SELECT buttons and then using the rotary knob to display the desired value.

Perform the following steps to enter a source or compliance value using the Adjust method:

1. Enable the cursor.

   With source-measure or compliance displayed, enable the cursor by either turning the rotary knob one detent position (left or right), or by pressing a SELECT button (◀ or ▶). The cursor position is indicated by the blinking digit.

2. Place the cursor on the digit to be changed.

   The cursor can be placed on any of the four LSDs (least significant digits) of the five-digit display. Pressing ◀ SELECT moves the cursor to the left. After the cursor is positioned on the MSD (most significant digit), each press of ◀ SELECT changes the display to the next higher range. Conversely, pressing SELECT ▶ moves the cursor to the right. After the cursor is positioned on the LSD, each press of SELECT ▶ changes the display to the next lower range.

3. Change the displayed value.

   Turning the rotary knob clockwise increments the displayed reading and conversely, turning the knob counter-clockwise decrements the reading. The reading can be incremented/decremented to +/− full scale of the selected range. Any digits to the right of the cursor are not affected unless the reading is incremented or decremented to full scale. In this case these digits become zeros since the unit cannot display a reading larger than full scale.

   When adjusting a source value, the polarity of the displayed reading can be changed by pressing +/− on the keypad.

4. Disable the cursor by pressing ENTER or CANCEL. Performing another operation, such as enabling autoranging, will also disable the cursor.

NOTE

Changing the display to a lower range with SELECT ▶ will cause a displayed reading that exceeds that range to default to the maximum reading for that range. For example, with 2.000V displayed on the 11V range, changing to the 1.1V range will default the display to 1.1000V.

Edit Method

In general, the Edit method simply consists of keying in the desired value from the keypad and pressing ENTER.

To enter a source value, the unit must be in the source-measure display state with the dc function selected. To enter a voltage source value, SOURCE V MEASURE I must be selected, and to enter a current source value, SOURCE I MEASURE V must be selected.

To enter a compliance value, the unit must be in the compliance display state (compliance enabled). To enter a voltage compliance value, SOURCE I MEASURE V must be selected, and to enter a current compliance value, SOURCE V MEASURE I must be selected.

The 0 through 9, +/− and EXP keys are used to key in values. The following examples demonstrate how to enter values.

Value	Key In	Displayed Reading		Press
+1.25V	1.25	+1.25	VOLTS	ENTER
−2.236V	+/−2.236	−2.236	VOLTS	ENTER
+3.26mA	.00326	+.00326	AMPS	ENTER
+3.26mA	3.26EXP+/−3	+3.26E−3	AMPS	ENTER

When a value is entered, the Source Measure Unit will go to the optimum source or compliance (measurement) range. A higher source or compliance (measure) range can be selected with the SELECT buttons. SELECT ◀ will uprange the unit while SELECT ▶ will downrange it. Selecting a range that is lower than the displayed value will default the unit to the maximum source or measure value for that range.

NOTES

1. Exponent (EXP) allows values to be entered in scientific notation form. The example value reads as +3.26 $\times 10^{-3}$ amps, which is 3.26mA.
2. Entering a value that exceeds the maximum source or compliance capability of the unit will default to the maximum value.
3. Entering a value that contains more digits than source or compliance resolution allows will result in the value being rounded. For example, entering a value of +1.2345V will round to +1.235V

2.9.2 Entering Other Operating Parameters

Parameter selections for other Source Measure Unit features are menu driven. The paragraphs that contain the data entry procedures for these features are listed as follows:

- Menu* (see paragraph 2.10)
- ∫Time (see paragraph 2.15)
- Filter (see paragraph 2.16)
- Sweep Create, Modify and Append (see paragraphs 2.19, 2.20, and 2.21)
- Trigger Setup (see paragraph 2.22)

* In addition to selecting operating parameters, menu is also used to perform self-tests which are explained in paragraph 2.10.

2.10 MENU

MENU
EXP
CANCEL
ENTER

Menu is a function of front panel operation. However, many of the operations performed by menu can also be performed over the IEEE-488 bus. Bus operation information will be provided where appropriate.

Menu is used to check and/or change certain aspects of Source Measure Unit operation and perform self test. These include:

- Delay for dc operation
- Default delay (on or off)
- Sensing (local or remote)
- Ac line frequency (50 or 60Hz)
- IEEE-488 address
- Display Test
- Memory Test
- Factory initialization

Menu is enable by pressing the MENU button and is denoted by the indicator. Menu is disabled by again pressing MENU.

The structure for menu items is shown in Figure 2-28. When menu is enabled, the Source Measure Unit will display the first operation menu item; dc delay. Any one of the eight menu items can be displayed with the rotary knob.

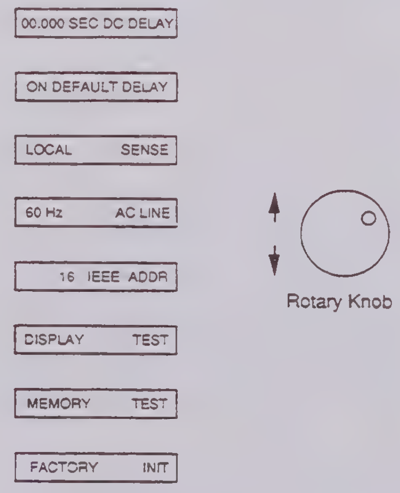


Figure 2-28. Menu Items

General Procedure

Perform the following steps to change a menu item parameter, perform a self test or perform factory initialization:

Step 1 : Press MENU to enter the menu display state.

Step 2: Use the rotary knob to display the desired menu item

Step 3: To perform a self test or factory initialization (DISPLAY TEST, MEMORY TEST or FACTORY INIT displayed), proceed to step 4. Otherwise:

1. To change DC DELAY or IEEE ADDR, use the keypad to key in the new value.
2. To change DEFAULT DELAY, SENSE or AC LINE, use the SELECT buttons to display the alternate parameter.

Step 4: Press ENTER.

Step 5: Repeat steps 2, 3 and 4 as needed. Exception: MENU will disable if FACTORY INIT is performed.

Step 6: Press MENU to return to the source-measure display state.

General MENU Rules

1. The MENU button toggles between the menu display state and the normal source-measure display state.
2. The rotary knob displays a menu item, while the SELECT buttons or keypad is used to change the displayed parameter.
3. ENTER must be pressed to enter a new parameter.
4. When a parameter for DC DELAY, DEFAULT DELAY, SENSE, AC LINE or IEEE ADDR is ENTERed, the next menu item will be displayed.
5. A keyed-in parameter can be cancelled by pressing CANCEL before ENTER.
6. The Source Measure Unit will return to the source-measure display state (MENU disabled) when FACTORY INIT is performed.

Detailed information and a step-by-step procedure for each menu item is provided by the following paragraphs.

2.10.1 Dc Delay

Dc delay is used exclusively for dc operation. Dc delay does not affect the sweep delay for sweep operation and conversely, setting a sweep delay does not affect the dc delay. Dc delay is used to provide additional time for the source to settle if its output level should change.

For a resistive load, dc delay is not necessary and can be set to zero seconds. Otherwise, the amount of delay needed is determined by the RC time constant of a load. Five time constants (5RC) provides 99% settling.

Dc delay can be set from 0sec to 65sec with one millisecond resolution.

To check the present dc delay and other menu item parameters, simply enable MENU and use the rotary knob to scroll through the menu items. If no changes are to be made, press MENU to return to the source-measure display state.

To change dc delay, perform the following steps:

1. With MENU enabled, turn the rotary knob until the dc delay is displayed. For example, if the delay is 0sec, the following message will be displayed:

   00.000 SEC DC DELAY

2. Using the keypad, key in the desired delay period in seconds (00.000 to 65.000).
3. Press ENTER. The next menu item will be displayed.
4. If no other menu actions are to be taken, disable MENU to return to the source-measure display state.

IEEE-488 Bus Operation

Over the bus, dc delay, source (bias) value and source range are programmed at the same time using the B command. See paragraph 2.11 for further information.

2.10.2 Default Delay

Default delay is a short delay (up to 360msec) that is used to allow for internal settling on the low current ranges

(10µA and under). The default delay is separate from the user programmed delay.

The time period of the default delay depends on which current range (source or measure) that the Source Measure Unit is on. The default delay times are listed in Table 2-4. The delay time period for each current range in the table generally reflects 5 RC time constants of settling.

Table 2-4. Default Delay

Range Source or Measure	Delay (msec)
1nA	360
10nA	75
100nA	20
1µA	5
10µA	2
100µA	0
1mA	0
10mA	0
100mA	0
1A	0

When default delay is enabled (ON), the total delay period before each measurement includes the default delay and the user programmed delay. With default delay disabled (OFF), the total delay period includes only the user programmed delay. However, with AUTORANGE (measure) enabled, the default delay time periods will be imposed even with default delay disabled (OFF).

Usually, default delay is left enabled unless you are trying to optimize a test for maximum speed. In that case, default delay is disabled and the lowest user programmed delay that will achieve acceptable results is used.

To check the status of default delay and other operation menu item parameters, simply enable MENU and use the rotary knob to scroll through the menu items. If no changes are to be made, disable MENU to return to the source-measure display state.

Perform the following steps to change the status of default delay:

1. With MENU enabled, turn the rotary knob until the default delay is displayed. For example, if default delay is presently disabled, the following will be displayed:

   OFF DEFAULT DELAY

2. Use the SELECT buttons to change the status of default delay. SELECT ▶ enables default delay, and ◀ SELECT disables it.
3. With the desired status displayed, press ENTER. The next menu item will be displayed.
4. If no other menu actions are to taken, disable MENU to return to the source-measure display state.

NOTES

1. Cycling power will not affect the status of the default delay. If it was previously disabled (OFF), it will power up in the disabled state. Conversely, if it was enabled, it will power up in the enabled state.
2. Factory initialization will enable default delay.
3. For pulse sweeps, selecting the alternate default delay state (on or off) may cause delay times to be recalculated by the Source Measure Unit in order to maintain the programmed ON and OFF times.

IEEE-488 Bus Operation

The W command is used to program default delay.

W0 = Disable default delay
W1 = Enable default delay

HP BASIC 4.0 Programming Examples:

OUTPUT 716; "W0X"	Disable default delay.
OUTPUT 716; "W1X"	Enable default delay

Complete information on the IEEE-488 bus and this command can be found in Section 3 of this manual.

2.10.3 Sense

The Source Measure Unit has local or remote sensing capability. When using remote sensing, sense lines are extended to the DUT.

When the Source Measure Unit is programmed to source V, sensing provides a feedback voltage that is measured and compared to the programmed voltage level. If the feedback voltage is less than the programmed voltage level, then the voltage source is increased until the feedback voltage equals the programmed voltage level. In local, sensing is performed at the output of the Source Measure Unit. In remote, external sense leads are connected to the load, thus, sensing is performed at the load. Remote sensing compensates for test lead IR drop, ensuring that the programmed voltage level is delivered to the load.

When sourcing I, local sensing is used to measure voltage at the output terminals. In remote sensing, external sense connections are made across the load. Thus, the subsequent voltage reading is the actual voltage drop across the load. Test lead IR drops are not included in the measured reading.

Remote sensing should always be used when sourcing or measuring 1mA or more. Sourcing or measuring 1mA or more indicates that the load impedance is relatively low. Since this low impedance load forms a voltage divider with the test lead resistance, the IR drop across the test leads becomes significant. Thus, in local sense, the voltage reading does not reflect the true voltage drop across the load. Instead, the reading includes the IR drop across the test leads.

Remote sense connections are covered in paragraph 2.3.

WARNING

With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. Never change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

When sourcing voltage, the output voltage is sensed (measured) and fed back to the voltage source (V_{SOURCE}). If the sensed voltage is lower than the programmed voltage, V_{SOURCE} is increased until the sensed voltage equals the programmed voltage. In the case of an open remote sense lead, the sensed voltage (0V) will never equal the programmed voltage. Thus, to compensate, V_{SOURCE} will increase to its maximum level.

To check the status of sense and other operation menu item parameters, simply enable MENU and use the rotary knob to scroll through the menu items. If no changes are to be made, disable MENU to return to normal operation.

Perform the following steps to select the alternate sense setting:

1. With MENU enabled, turn the rotary knob until the present sense setting is displayed. For example, if local sense is currently selected, the following will be displayed:

   SENSE LOCAL

2. Use the SELECT buttons to select the alternate setting. SELECT ▶ selects remote sense and ◀ SELECT selects local sense.
3. With the desired sense selected, press ENTER. The next menu item will be displayed.
4. If no other menu actions are to be taken, disable MENU to return to the source-measure display state.

NOTES

1. The unit powers up to local sensing.
2. Factory initialization places the unit in local sense.
3. Internally, the Source Measure Unit will go ot local sensing when it is placed in standby. When operate is enabled, the Source Measure Unit will go to the programmed sense selection (remote or local).

Source/Sense Voltage Differential

When configured as a voltage source, the remote sense leads are typically connected in close proximity to the source leads by the DUT. As a result, the voltage difference between source and sense is virtually zero. The very small difference is caused by the voltage drop in the source leads.

However, there may be test situations that require the remote sense leads and source leads to be connected to different parts of a circuit that have a significant voltage differential between them.

The maximum allowable voltage difference between OUTPUT LO and SENSE LO is 4V. Exceeding this voltage difference between source low and sense low will result in erratic operation.

The maximum allowable voltage differential (V_{MAX}) between OUTPUT HI and SENSE HI is defined by the following equation. Exceeding this voltage difference between source high and sense high will result in erratic operation.

$$V_{MAX} = 12 - 10(V_{OUT}/V_{FS})$$

where;

V_{MAX} = Maximum allowable voltage difference between OUTPUT HI and SENSE HI
V_{OUT} = Output Voltage
V_{FS} = Full scale voltage range

For example, if 5V is sourced on the 11V range, the maximum allowable voltage differential between source and sense is:

$$V_{MAX} = 12 - 10(5V/11V) = 7.45V$$

IEEE-488 Bus Operation

The O command is used to program sense.

WARNING
With remote sensing enabled, an open sense lead will result in lethal voltages appearing at OUTPUT HI and GUARD. This voltage can cause injury or death, and damage external circuitry. Always make sure that the sense leads are properly connected before enabling remote sense. NEVER change connections with power applied. Be sure to always discharge and/or disconnect external power sources.

O0 = Local sense
O1 = Remote sense

HP BASIC 4.0 Programming Examples:

OUTPUT 716; "O1X"	Select remote sense
OUTPUT 716; "O0X"	Select local sense

Complete information concerning the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

2.10.4 Ac Line Frequency

The Source Measure Unit will operate on an ac line frequency of 50 or 60Hz. This menu item allows you to check or change the line frequency setting of the Source Measure Unit.

This adjusts the A/D converter to the proper integration time for line cycle integration.

To check the present ac line frequency setting and other menu operation item parameters, enable MENU and use the rotary knob to scroll through the menu items. If no changes are to be made, disable MENU to return to the source-measure display state.

Perform the following steps to select the alternate ac line frequency setting:

1. With MENU enabled, turn the rotary knob until the present ac line frequency setting is displayed. For example, if the line frequency is currently set to 60Hz, the following will be displayed:

   60Hz AC LINE

2. Use the SELECT buttons to select the alternate setting. SELECT ▶ selects 50Hz and ◀ SELECT selects 60Hz.
3. With the desired line frequency setting displayed, press ENTER. The next menu item will be displayed.
4. If no other menu actions are to be taken, disable MENU to return to the source-measure display state.

NOTE
Changing the ac line frequency with a front panel menu selection also changes the integration time if LINECYCLE PERIOD is presently selected. For example, a line frequency change from 60Hz to 50Hz also changes the integration time from 16.667msec to 20msec.

NOTE

Both power up and factory initialization will default the unit to the last programmed line frequency setting.

2.10.5 IEEE-488 Bus Address

This menu item allows you to check and/or change the IEEE address of the Source Measure Unit. At the factory, the Models 236, 237 and 238 are set to address 16. Valid addresses are 00 to 30.

To check the present IEEE address and other operation menu item parameters, enable MENU and use the rotary knob to scroll through the menu items. If no changes are to be made, disable MENU to return to normal operation.

Perform the following steps to change the IEEE address:

1. With MENU enabled, turn the rotary knob until the present IEEE address is displayed. For example, if the present address is 16, the following will be displayed:

   16 IEEE ADDR

2. To change the IEEE address, key in the new value (00 to 30).
3. With a valid address keyed into the display, press ENTER. The next menu item will be displayed.
4. If no other menu actions are to be taken, disable MENU to return to the source-measure display state.

2.10.6 Display Test

The display test is used to check for defective display LED segments and front panel indicator lights. When this test is run, all display segments and indicator lights will be turned on for several seconds.

Perform the following steps to perform the display test:

1. With MENU enabled, use the rotary knob to display the following message:

   DISPLAY TEST

2. Press ENTER. All display segments and indicator lights will turn on for several seconds. The next menu item will be displayed.
3. If no other menu action are to be taken, disable MENU to return to the source-measure display state.

IEEE-488 Bus Operation

The J2 command is used to perform the display test from over the bus.

HP BASIC 4.0 Programming Example:

OUTPUT 716; "J2X"	Perform display test

2.10.7 Memory Test

The memory test is used to perform tests on its memory elements. If the tests fail, one or more error messages will be displayed. A brief explanation of any displayed error message is contained in Table 2-3. In the event of a failure, refer to the service manual for troubleshooting information.

NOTE
If the instrument is still under warranty and if a problem develops, it should be returned to Keithley Instruments, Inc. for repair.

Perform the following steps to perform the memory test:

1. With MENU enabled, use the rotary knob to display the following message:

   MEMORY TEST

2. Press ENTER to perform the test. After the test is completed, the next menu item will be displayed.
3. If no other menu actions are to be taken, disable MENU to return tot he source-measure display state.

IEEE-488 Bus Operation

The J1 command is used to perform the memory test from over the bus.

HP BASIC 4.0 Programming Example:

OUTPUT 716; "J1X"	Perform memory test

2.10.8 Factory Initialization

When powered up, the Source Measure Unit will, for the most part, initialize to whatever was previously programmed. These are the power up default conditions and are summarized in Table 2-5. A checkmark (√) indicates that the unit will initialize to whatever was previously programmed.

The Source Measure Unit can be returned to factory default conditions which are also listed in Table 2-5.

Perform the following steps to initialize the unit to factory default conditions:

1. With MENU enabled, use the rotary knob to display the following message:

FACTORY INIT

2. Press ENTER. The Source Measure Unit will initialize to the factory default conditions listed in Table 2-5.
3. If no other menu actions are to be taken, disable MENU to return to the source-measure display state.

IEEE-488 Bus Operation

The J0 command is used to restore factory default conditions.

HP BASIC 4.0 Programming Example:

OUTPUT 716; "J0X"	Restores factory default conditions

Table 2-5. Factory and Power-up Default Conditions

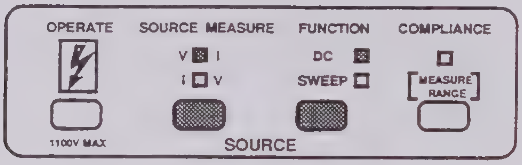
	Factory Default	Power up Default
Autorange (Measure)	Disabled	√
Bias (dc Function)		
Source value	0V/0mA	√
Source range	11V (236, 237); 15V (238) / 10mA	√
Dc delay value	0msec	√
Calibration Step**	0	0
Compliance		
Value	10mA/10V	√
Range	10mA/11V (236,237); 15V (238)	√
Default delay	Enabled	√
EOI and bus hold-off**	EOI enabled, hold-off on X	EOI enabled, hold-off on X
Filter	Disabled	√
Function	dc	dc
1100V Range Control**		
236/238	Disabled	Disabled
237	Enabled	√

√ User's previously programmed condition
* Front panel only
**IEEE-488 Bus only

Factory and Power-up Default Conditions (Cont.)

	Factory Default	Power up Default
IEEE address*	√	√
∫ Time	Fast period (416µsec)	√
Line frequency*	√	√
Operate/standby	Standby	Standby
Output format**		
Items	Source value only	Source value only
Format	ASCII with prefix and suffix	ASCII with prefix and suffix
Lines	1 line of dc data	1 line of dc data
Output Sense	Local	Local
Source	V-source	√
SRQ**		
Mask	None	None
Compliance	SRQ during idle, measure or delay phase	SRQ during idle, measure or delay phase
Stored ASCII String**	√	√
Suppression		
Control	Disabled	Disabled
Value	0V, 0mA	0V, 0mA
Sweep buffer	Cleared	Previous sweep data retained
Sweep create/append	Linear stair	√
Start value	1V/1mA	√
Stop value	10V/10mA	√
Source range	11V (236, 237); 15V (238) / 10mA	√
Delay time	0msec	√
Number of Points (Pulses)	10	√
Step value	1V/1mA	√
Log points	10 points/decade	√
Pulse on time	100msec	√
Pulse off time	100msec	√
Sweep modify	First point*	First point*
Terminators**	CR LF	CR LF
Trigger configuration		
Origin	Internal (Immediate)	√
Trig in	Continuous	√
Trig out	None	√
Sweep End	Disabled	√
Trigger control	Enabled	Enabled

2.11 SELECT SOURCE AND FUNCTION



The available voltage source and current source ranges are listed in Table 2-6 and Table 2-7. The selected source will behave as a constant dc source when in the dc function, or sweep through a pre-defined list of source values and delay times when in the sweep function.

Table 2-6. Voltage Source Ranges

Model	Range (Max Output)	Resolution
236, 237 238	±1.1000V ±1.5000V	100µV
236, 237 238	±11.000V ±15.000V	1mV
236, 237, 238	±110.00V	10mV
237	±1100.0V*	100mV

Table 2-7. Current Source Ranges

Range (Max Output)	Resolution
±1.0000nA	100fA
±10.000nA	1pA
±100.00nA	10pA
±1.0000µA	100pA
±10.000µA	1nA
±100.00µA	10nA
±1.0000mA	100nA
±10.000mA	1µA
±100.00mA	10µA
±1.0000A*	100µA

*Model 238 only

Each source (V and I) will "remember" its own unique setup configuration. Setup configuration components that are remembered for each source include:

- Source value and range
- Compliance limit and range
- Integration time
- Filter
- Autorange
- DC delay
- Default delay
- Sense
- Sweep Parameters

The SOURCE MEASURE button toggles the Source Measure Unit between Source V, Measure I and Source I, Measure V. The FUNCTION button toggles the Source Measure Unit between dc operation and sweep operation.

With the dc function selected, the present source value will be displayed and can be changed to any value within the source range of the Source Measure Unit.

Changing the dc function source level also changes the bias level of the sweep that is currently defined. Conversely, changing the bias level of a sweep will change the dc function source to that level.

Perform the following steps to set a source value (V or I) for dc operation:

1. If the desired source is not already selected, press SOURCE MEASURE to select it.
2. If dc operation is not already selected, press FUNCTION to select it (DC light on).
3. Set the source value using the Adjust or Keypad method of data entry.

   Adjust Method:
   Use the rotary knob and the SELECT buttons to enter the source value into the display.

   Keypad Method:
   A. Key in the source value using the DATA ENTRY keypad.
   B. Press ENTER. If the MANUAL TRIGGER light is blinking, the source value will not be displayed until the MANUAL TRIGGER button is pressed.

Changing the Source Range (dc operation)

The position of the decimal point indicates the source range. For example, a reading of +002.00V indicates that the 110V range is selected, while a reading of +02.000V indicates that the 11V or 15V range is selected.

To select a different source range, use the SELECT buttons.◀ SELECT upranges and SELECT ▶ downranges. Note that if you select a range that cannot accommodate the present source value, the Source Measure Unit will default to the maximum value for the that range.

NOTES

1. Anytime SOURCE MEASURE is pressed, the following actions will occur:
   A. The displayed source value will default to zero (0.0000V or 000.00mA).
   B. The MANUAL TRIGGER light will start blinking. The Source Measure Unit will not display the programmed source value until a trigger occurs (i.e. MANUAL TRIGGER button pressed).
   C. If the Source Measure Unit was in operate, it will go into standby.
2. Anytime FUNCTION is pressed, the following actions will occur:
   A. The MANUAL TRIGGER light will start blinking.
   B. If the Source Measure Unit was in operate, the source will still be applied to the output but it will not be measured (i.e. "+1.0000 V ——.——mA"). To resume measurements, the Source Measure Unit must be in the dc function and a trigger must occur.
3. A dc function source value cannot be set if in the sweep function except with the bias parameter of the sweep.
4. When power is cycled the dc function will be selected. The source (V or I), bias value, and range will power up to whatever was previously programmed.
5. Factory initialization will place the unit in V-source, dc function, with a source value of 0V, on the 11V or 15V range. The I-source will be set to source 0mA on the 10mA range.
6. When a source range change occurs, the Source Measure Unit will momentarily output 0V or 0mA. This could create an undesirable transient in an otherwise smooth sweep. In situations where the transient is not tolerable, a fixed source range should be used to eliminate range changes.

IEEE-488 Bus Operation

The F command is used to program source and function.

F0,0 = Source V Measure I (dc operation)
F0,1 = Source V Measure I (sweep operation)
F1,0 = Source I Measure V (dc operation)
F1,1 = Source I Measure V (sweep operation)

For dc operation, the B command is used to program the source (bias) value, source range, and delay. The command is sent in the following form:

B (bias),(range),(delay)

Bias: A valid source value within the source range of the Source Measure Unit.

Range: A value that corresponds to the source range of the Source Measure Unit. If not using auto, the selected range must be large enough to accommodate the bias value.

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1μA	1100V (237)
5 =	10μA	*
6 =	100μA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option

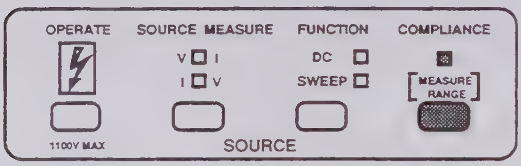
Delay: Dc delay in msec (0 to 65000)

HP BASIC 4.0 Programming Example:

OUTPUT 716; "F1,0X"	Select Source I Measure V for dc operation.
OUTPUT 716; "B36E-9, 3, 500X"	Set source to 36nA (exponent form shown), 100nA range, and dc delay to 0.5 seconds.
OUTPUT 716; "H0X"	Apply trigger to update display.

Complete information concerning the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

2.12 SET COMPLIANCE AND MEASUREMENT RANGE



Compliance limits are set in order to protect external circuitry (i.e. DUT) from damage. When sourcing voltage, a current compliance limit is set. The Source Measure Unit will never source a current that will exceed the programmed current compliance limit. For example, assume that current >10mA will damage a current-sensitive 2kΩ device. Thus, the current compliance limit would be set to 10mA. If the Source Measure Unit is programmed to source 40V it would normally source 40V at 20mA to the 2kΩ load (40V / 2kΩ = 20mA). However, since the current compliance limit is set at 10mA, the Source Measure Unit will only source 20V at 10mA (2kΩ × 10mA = 20V).

Conversely, when sourcing current, a voltage compliance limit is set. The Source Measure Unit will never source a voltage that will exceed the programmed compliance voltage limit.

> CAUTION
>
> **With an external source or energy storage device connected to the output, current is not limited when in Source I Measure V. Refer to paragraph 2.26 for precautions against excessive current that could damage the Model 236/237 or external circuitry.**

Setting compliance sets the maximum measurement range of the Source Measure Unit. For example, setting a compliance of 5V will mean that the Source Measure Unit can measure up to but not more than ±5V. A larger measurement range can be selected (if available), but again, the maximum measured reading will be the compliance value. A measurement range that is lower than the compliance value cannot be selected, unless AUTORANGE is enabled. Trying to do so from the front panel will default the displayed compliance value to the maximum reading of the selected measurement range.

With AUTORANGE enabled, the Source Measure Unit will automatically downrange to the lowest possible (most sensitive) range to make measurements.

When compliance is selected, the present compliance limit is displayed and can be changed to any value within the measurement range of the Source Measure Unit. The measurement ranges of the Source Measure Unit are listed in Table 2-8 and Table 2-9.

Table 2-8. Current Measurement Ranges

Range (Max Output)	Resolution	
	4d	5d
±1nA	100fA	10fA
±10nA	1pA	100fA
±100nA	10pA	1pA
±1μA	100pA	10pA
±10μA	1nA	100pA
±100μA	10nA	1nA
±1mA	100nA	10nA
±10mA	1μA	100nA
±100mA	10μA	1μA
±1A*	100μA	10μA

*Model 238 only

Table 2-9. Voltage Measurement Ranges

Model	Range (Max Output)	Resolution	
		4d	5d
236, 237 238	±1.1000V ±1.5000V	100μV	10μV
236, 237 238	±11.000V ±15.000V	1mV	100μV
236, 237, 238	±110.00V	10mV	1mV
237	±1100.0V	100mV	10mV

Perform the following steps to check and/or change the compliance limit of the currently selected source.

1. Press COMPLIANCE to enable and display the compliance limit. For example, if the present compliance limit for the voltage source is ±50mA, the following will be displayed:

   ±050.00mA COMPLI

2. If the displayed compliance limit is not to be changed, disable compliance by again pressing COMPLIANCE to return to normal operation. Otherwise, change the compliance limit using the Adjust or Edit method of data entry. If not familiar with the entry methods, refer to paragraph 2.9 for complete details.

Adjust Method:

Use the SELECT buttons and the rotary knob to set a new compliance limit. The SELECT buttons are used to position the cursor (flashing digit) and to change ranges, and the rotary knob is used to change the value.

With the desired compliance limit displayed, press COMPLIANCE to return to the normal source-measure display state. The compliance limit of the instrument will not update to the "pending" value until the next trigger occurs.

The "pending" compliance limit value can be viewed as follows: First, enable COMPLIANCE to display the present compliance limit value. Then display the "pending" compliance limit value by turning the rotary knob one detent position (left or right), or by pressing either SELECT key. This "pending" value can be modified as previously explained or retained by pressing CANCEL.

With AUTORANGE enabled, the Source Measure Unit will internally go the lowest possible (most sensitive) compliance range. On the lowest compliance range (1nA, 1.1V or 1.5V), the lowest possible compliance value is 100 counts (0.0100nA or 0.0100V). Values less than 100 counts can be displayed, but the actual compliance will default to 10pA or 10mV.

With AUTORANGE disabled, the lowest possible compliance value is 100 counts of the selected range. For example, on the 100mA compliance range, the displayed limit can be adjusted from 000.00mA to 000.99mA but will actually be set to 001.00mA (100 counts).

Edit Method:

To set a new compliance limit, key in the desired value using the DATA ENTRY keypad and press ENTER. The Source Measure Unit will go to the lowest possible (most sensitive) range. The lowest compliance value is 1pA or 1mV. Lower values can be entered and displayed, but the actual compliance will be 1pA or 1mV.

To select a higher measurement range, again enable COMPLIANCE and press ◀ SELECT. Press COMPLIANCE to return to the normal source-measure display state.

The compliance limit of the instrument will not update to the new value until the next trigger occurs.

NOTES

1. Upon power up, the compliance limit and range will be set to whatever was previously programmed.
2. Factory initialization will set the compliance to 10mA on the 10mA measurement range. For the I source, compliance will be set to 10V on the 11V or 15V measurement range.
3. Pulse sweeps - If changing compliance causes the default delay time period to change (if enabled), delay times will be recalculated by the Source Measure Unit in order to maintain the programmed on and off times.
4. Dc operation - When the measurement range is changed, the range change does not actually occur until the next input trigger occurs.

Measure Only

The Source Measure Unit can be used as a stand alone voltmeter or current meter. The basic configurations are explained in paragraph 1.2 in GETTING STARTED. More detailed information for using the Source Measure Unit as an electrometer is provided in SOURCE-MEASURE CONSIDERATIONS.

IEEE-488 Bus Operation

The L command is used to program compliance and measurement range, and is sent in the following form:

L(compli),(range)

Compli: A valid compliance value within the measurement range of the unit.

Range: A value that corresponds to the measurement range of the Source Measure Unit. A selected fixed measurement range must be equal to or higher than the compliance value.

	I-measure	V-measure
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*

8 = 10mA *
9 = 100mA *
10 = 1A (238) *

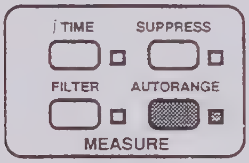
*Illegal V-source option

HP BASIC 4.0 Programming Example:

OUTPUT 716; "F1,0X"	Select Source I Measure V (dc operation)
OUTPUT 716; "L5,2X"	Set compliance to 5V and select 11V or 15V measurement range.

Complete information concerning the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

2.13 AUTORANGE



With AUTORANGE enabled, the Source Measure Unit will go to the lowest possible (most sensitive) range to make the measurement. For example, with a 3V compliance limit 11V or 15V (Model 238) range, 0.5V will be measured on the 1.1V or 1.5V (Model 238) range if autorange is enabled.

With a pulse sweep saved in the sweep buffer, the message "PULSE TIME NOT MET" will be displayed whenever AUTORANGE is enabled. This message indicates that the programmed on and off times of the pulse will most likely not be met when a measurement range change occurs. If unspecified pulses cannot be tolerated in a test, use a fixed measurement range to avoid range changes.

The AUTORANGE button toggles between autorange and the fixed range selected when compliance was set. When AUTORANGE is enabled, its indicator light will be on.

Autorange Thresholds — When a measured reading is increasing, an autorange to the next highest range will occur when full scale is surpassed. (As described in paragraph 3.7.2, the instrument actually upranges to the compliance range, then downranges to the required measure range.) For example, assume a measured reading of +0.8971mA (1mA range). The Model 236/237/238 will autorange up to the 10mA range when the reading surpasses +1.0000mA.

When a measured reading is decreasing, autorange to the next lower range will occur when 9% of full scale is reached. For example, assume a reading of +01.000mA (10mA range). The Model 236/237/238 will autorange to the 1mA range when the reading decreases past +00.900mA. For voltage ranges, downranging will occur at 8.1% of full scale, with the exception of the 1.5V and 15V ranges of the Model 238, where downranging occurs at 9% of full scale.

NOTES:

1. When upranging or if a measurement range change occurs while the unit is in compliance (COMPLIANCE indicator blinking or when upranging), the Source Measure Unit will momentarily output 0V or 0mA.
2. Autorange should not be used when optimum speed is required. The effects of autorange on sweep performance is covered in paragraph 3.7.3.

IEEE-488 Bus Operation

Over the bus, the compliance limit and measurement range (including autorange) are set using the L command (see the previous paragraph).

Note that autorange can be controlled by sending only the range option with the L command. The compliance option need not be sent. The format for sending only the range option is as follows:

L,(range)

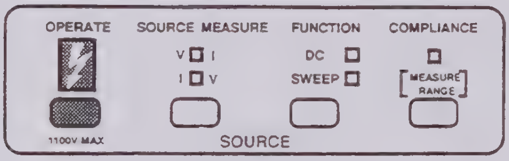
As defined in paragraph 2.12, range option 0 selects autorange. Thus, sending L,0X over the bus will enable AUTORANGE. Sending any other valid range option (one through ten) will disable AUTORANGE. A valid fixed measurement range is equal to or higher than the compliance limit.

HP BASIC 4.0 Programming Example:

```
OUTPUT 716; L,0X          Enable autorange
```

Complete information concerning the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

2.14 OPERATE



A source cannot be applied to the output unless the unit is in operate. The unit can only be placed in operate when it is in the source/measure display state. The unit can be placed in standby (OPERATE light off) while the unit is in any display state. Toggling the sources (V to I, or I to V) will also place the unit in standby.

DC Operation — With the dc function selected, enabling operate will apply the source to the output. If the MANUAL TRIGGER light is blinking, a trigger is needed to start making measurements.

Sweep Operation — With the sweep function selected, enabling OPERATE will source (but not measure) the bias level of the sweep. The sweep itself will not start until the appropriate trigger occurs (as denoted by the blinking MANUAL TRIGGER light).

WARNING
To avoid electric shock, always assume that a hazardous voltage is applied to the output when OPERATE is enabled.

Operate toggles the unit between the operate and standby states. When in the operate state, the OPERATE light is turned on. When in standby, the "STBY" message will be displayed when the unit is in the source/measure display mode.

Standby Definition

In standby, the output of the Model 236/237/238 is determined by whether it is in Source I Measure V, or Source V Measure I.

Source I Measure V — In standby, the Source Measure Unit will output 0V on the 1.1V (Model 236/237) or 1.5V (Model 238) compliance voltage range. The compliance current limit is determined by the programmed current source value and range. If the programmed current source value is on a range lower than the 100µA range, then the compliance current limit will be 100µA on the 100µA range. The following examples illustrate this:

Programmed Current	Standby Current
20nA on the 100nA range	100µA on the 100µA range
5µA on the 10µA range	100µA on the 100µA range

If the programmed current source value is on the 100µA range or above, that range will be used. The current value used is the programmed current value or 100µA, whichever is greater. The following examples illustrate this:

Programmed Current	Standby Current
90µA on the 100µA range	100µA on the 100µA range
120µA on the 10mA range	120µA on the 10mA range
1mA on the 100mA range	1mA on the 100mA range

Source V Measure I — In standby, the Source Measure Unit will output 0V on the 1.1V (Model 236/237) or 1.5V (Model 238) voltage source range. The compliance current limit is determined by the programmed current compliance value and range. If the programmed current compliance value is on a rnage lower than the 100mA range, then the compliance current limit will be 100mA on the 100mA range. The following examples illustrate this:

Programmed Current	Standby Current
20nA on the 100nA range	100µA on the 100µA range
5µA on the 10µA range	100µA on the 100µA range

If the programmed current compliance value is on the 100µA rnage or above, that range will be used. The compliance current limit will be the programmed current value or 1% of the programmed range, whichever is greater. The following examples illustrate this:

Programmed Current	Standby Current
50µA on the 100µA range	50µA on the 100µA range
150µA on the 100mA range	1mA on the 100mA range
100µA on the 1mA range	100µA on the 1mA range

Perform the following steps to place the unit in the operate state:

1. With the unit in the source-measure display state, make sure the unit is in standby (OPERATE light off and "STBY" message displayed). The following example display message denotes the standby state:

   +0.0000 V STBY mA

   If the unit is not in standby, toggle OPERATE.
2. Configure the operating parameters of the unit as desired (i.e. select source and function, set compliance, enable AUTORANGE, etc).
3. With the unit in the source-measure display state, press OPERATE. The source will be applied to the output. If the MANUAL TRIGGER light is blinking, a trigger will be needed to start measurements (dc operation) or to start a sweep (sweep operation).

NOTES:

1. Upon power up or if factory initialization is performed, the unit will go into standby.
2. If an interlock cable is connected, the interlock switch must be closed before OPERATE will enable.
3. Internally, the Source Measure Unit will go to local sensing when it is placed in standby. When operate is enabled, the Source Measure Unit will go to the programmed sense selection (remote or local).

IEEE-488 Bus Operation

The N command is used to control standby/operate.

N0 = Standby
N1 = Operate

HP BASIC 4.0 Programming Example:

In addition to demonstrating the N command, other commands already explained are used to show how they are all used together to source a voltage.

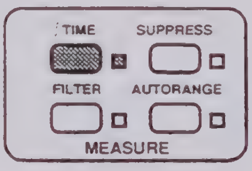
```
10  REMOTE 716
20  OUTPUT 716; "F0,0X"       Select V-Source and dc
                              function.
30  OUTPUT 716;               Set source to 1V on 1.1V
    "B1,1,500X"               or 1.5V range and 1/2
                              second delay.
40  OUTPUT 716; "L.01,0X"     Set compliance to
                              10mA and select auto
                              measurement range.
50  OUTPUT 716;               Program for trigger on
    "R1T1,0,0,0X"             GET.
60  TRIGGER 716               Provide trigger stimu-
                              lus.
70  OUTPUT 716; "N1X"         Place unit in operate.
80  END
```

When the program is run, 1V will be applied to the output.

Note: Line 50 configures the instrument to trigger on a group execute trigger (GET) which occurs in line 60. See paragraph 2.22 for trigger information.

Complete information concerning the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

2.15 ∫TIME



The integration (measure) time for A/D conversions and subsequent usable measurement resolution is selectable from the front panel and over the IEEE-488 bus. Table 2-10 summarizes the integration time selections. Notice that when LINECYCLE PERIOD is selected, the integration time depends on the line frequency setting (50 or 60Hz) of the Source Measure Unit.

The selectable integration rates offer a trade off between speed, resolution and noise rejection. The fast integration period provides the fastest measurements and should be used when speed is the most important consideration. At the other extreme, the line-cycle integration period provides the slowest but most stable (quieter) measurements. The medium and line cycle integration periods provide 5-digit resolution.

The ∫TIME control is used to check and/or change the integration period of the Source Measure Unit. When enabled (light on), the currently selected integration period will be displayed. The other integration period selections can be displayed with the SELECT buttons as shown in Figure 2-29.

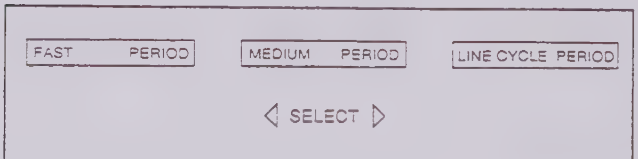


Figure 2-29. Integration Time Selections

Perform the following steps to check and/or change the integration period of the Source Measure Unit:

1. Press ∫ TIME (light on) to display the integration period. For example, if the medium integration period is currently selected, the following will be displayed:

   MEDIUM PERIOD

2. If the displayed integration period is not to be changed, press ∫ TIME to return to normal operation. Otherwise, display the desired integration period using the SELECT buttons and press ENTER. The Source Measure Unit will return to normal operation.

NOTES

1. A unique integration time can be set for each source.
2. The unit will power up to the last programmed integration time for the selected source.
3. Factory initialization will program both sources for fast (416µsec) integration.
4. Line cycle integration time is determined by the ac line frequency setting (see paragraph 2.10.4). Changing the ac line frequency with a front panel menu selection also changes the integration time if LINECYCLE PERIOD is presently selected. For example, a line frequency change from 60Hz to 50Hz also changes the integration time from 16.667msec to 20msec.
5. For pulse sweeps, selecting an alternate integration rate causes delay times to be recalculated by the Source Measure Unit in order to maintain the programmed ON and OFF times.
6. Total measurement time for each reading is dependent on the number of conversions averaged (filter) and the integration rate currently selected.

IEEE-488 Bus Operation

The S command is used to select the integration period.

S0 = Fast period (416µsec integration) at 4-digit resolution
S1 = Medium period (4msec integration) at 5-digit resolution
S2 = 60Hz line cycle period (16msec integration) at 5-digit resolution
S3 = 50Hz line cycle period (20msec integration) at 5-digit resolution

HP BASIC 4.0 Programming Example:

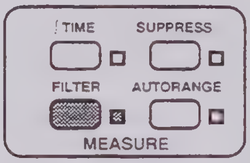
OUTPUT 716; "S1X"	Select the medium integration period

Complete information concerning the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

Table 2-10. Integration Periods and Resolution

Selection	Integration Time	Measurement Resolution
FAST PERIOD	416µsec	4 digits
MEDIUM PERIOD	4msec	5 digits
LINE CYCLE PERIOD	60Hz; 16.667msec 50Hz; 20msec	5 digits

2.16 FILTER



Filtering is used to stabilize noisy measurements. The unit does this by averaging a number of reading conversions and then displaying (or storing) the result. The number of readings that can be averaged (filtered) is 2, 4, 8, 16 or 32. FILTER disabled is synonymous to averaging one reading.

The more filtering used, the quieter the reading. However, filtering increases measurement time, thus decreasing unit speed. As a general rule, only use as much filtering as necessary.

The FILTER light denotes the status of the filter. If the light is on, the FILTER is enabled. If the light is off, FILTER is disabled. The FILTER button toggles between the filter selections and normal operation.

Perform the following steps to control the filter from the front panel:

1. Press FILTER. If its light was off (FILTER disabled), it will turn on. The present filter selection will be displayed. For example, if the FILTER is currently disabled the following is displayed:

   DISABLE FILTER

2. If no changes are to be made, press FILTER or ENTER to return to the source-measure display state. Otherwise, use the SELECT buttons to display the desired filter selection (see Figure 2-30).
3. Press ENTER.

NOTES

1. A unique filter value can be set for each source.
2. The unit will power up to the last programmed filter for the selected source.
3. Factory initialization will disable FILTER for both sources.
4. For pulse sweeps, the increased measurement time caused by filtering causes delay times to be recalculated by the Source Measure Unit in order to maintain the programmed ON and OFF times.
5. Total measurement time for each reading is dependent on the number of conversions averaged (filter) and the integration rate currently selected (see paragraph 2.15).

IEEE-488 Bus Operation

The P command is used to control the filter.

P0 = Filter disabled
P1 = Two readings averaged
P2 = Four readings averaged
P3 = Eight readings averaged
P4 = 16 readings averaged
P5 = 32 readings averaged

HP BASIC 4.0 Programming Example:

OUTPUT 716; "P3X"	FILTER enabled; eight readings averaged.
OUTPUT 716; "P0X"	FILTER disabled.

Complete information on the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

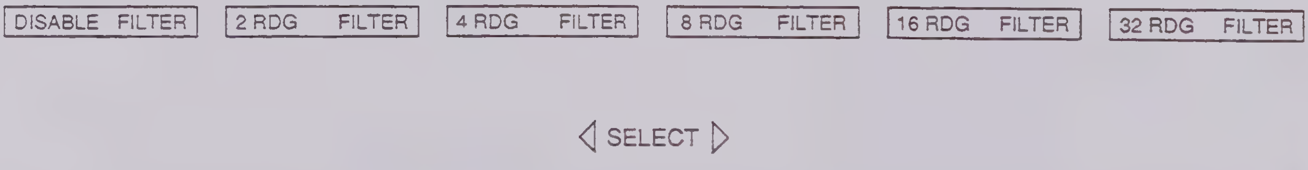
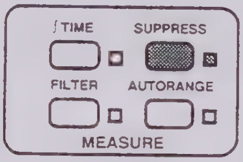


Figure 2-30. FILTER Selections

2.17 SUPPRESS



Suppression allows a stored offset value to be subtracted from subsequent measured readings. When SUPPRESS is enabled, the next conversion taken in OPERATE will be internally stored as a baseline. All subsequent readings will be the difference between the suppressed value and the actual signal level. The suppressed readings can be as small as the measurement resolution of the Source Measure Unit or as large as full range.

The baseline value maintains its value regardless of range. For example, if a 0.5V measured reading is suppressed on the 1.1V or 1.5V (Model 238) range, it will remain at 0.5V on the 11V, 15V (Model 238), 110V, and 1100V (Model 237) ranges.

A suppressed value is not saved for both the voltage source and the current source. The respective baselines will be lost when the sources are toggled.

Using suppression shifts the dynamic range of the measurement. At 4-digit resolution, up to ±11,000 counts (for volts) can be processed by the A/D and displayed. When a measurement is suppressed, the display treats that value as a zero, but the A/D converter does not. For example, if +4V is suppressed on the 11V range of 236/237, the display will read 0V, but the A/D converter will "see" +4V (4,000 counts). With +07.000 V displayed, the A/D converter is actually processing +11V (11,000 counts) which is the maximum. Thus, the dynamic measurement range has been shifted to a range of –15V to +7V.

Suppressing a value while in dc operation will process readings already stored in the sweep buffer. The suppressed value will be algebraically subtracted from every measurement point in the sweep. For example, assume the sweep buffer contains the following measured readings; 1mA, 2mA, 3mA and 4mA. Suppressing 0.5mA while in dc operation will change the sweep buffer readings to 0.5mA, 1.5mA, 2.5mA and 3.5mA. This allows you to run a sweep and then afterwards use suppression to cancel an offset. When SUPPRESS is later disabled, the readings in the sweep buffer will return to the measured values (1mA, 2mA, 3mA and 4mA).

The first measurement point of a sweep can be suppressed. Prior to starting the sweep, enabling SUPPRESS will cause its light to start blinking, indicating that it is waiting for a trigger to start the sweep. When the sweep is started, the first measurement point is suppressed, and subsequent measured points reflect the suppressed value. If SUPPRESS is disabled after the sweep is completed, the readings in the sweep buffer will return to the originally measured values.

WARNING

Voltage on the output may be larger than the displayed measured value. For example, if a 75V baseline is stored, a voltage of +100V will result in a displayed measured value of only +25V.

To use suppression, perform the following steps:

1. Cancel SUPPRESS if currently enabled.
2. For dc operation:
   - A. Configure the unit so that it will output a signal and display the measurement to be suppressed.
   - B. Press SUPPRESS. The displayed measurement will zero and all subsequent measurements will reflect the suppressed value.
3. For sweep operation:
   - A. Configure the unit for a sweep as explained in paragraph 2.19.
   - B. Press SUPPRESS. After the sweep is triggered to start, the first measurement will be suppressed. All subsequent measurements in the sweep will reflect the suppressed value.

NOTES

1. Factory initialization disables SUPPRESS for both sources.
2. When SUPPRESS is enabled, the first measurement will be used as the suppression value. The SUPPRESS indicator light will blink until that measurement is made. Be careful not to inadvertently change the source level before the first measurement is made.

IEEE-488 Bus Operation

The Z command is used to control suppression.

Z0 = Disable suppression
Z1 = Enable suppression

HP BASIC 4.0 Programming Example:

From the front panel or over the bus, program the the Source Measure Unit to apply a voltage or current to a suitable load. With a measured reading observed on the display, execute the following program statement:

OUTPUT 716; "Z1X"	Enable suppression

The display will zero, and the previous measured reading will be stored as the suppressed value. All subsequent measurements will reflect the suppressed value.

Complete information on the IEEE-488 bus and this command can be found in Section 3 IEEE-488 Reference.

Sweep Operation

2.18 BASIC SWEEP WAVEFORMS
2.19 CREATE SWEEP
2.19.1 Parameter Definitions
2.19.2 General Procedure
2.19.3 IEEE-488 Bus Operation
2.19.4 Fixed Level Sweep
2.19.5 Linear Staircase Sweep
2.19.6 Logarithmic Staircase Sweep
2.19.7 Pulse Sweep
2.19.8 Linear Staircase Pulse Sweep
2.19.9 Log Staircase Pulse Sweep
2.20 APPEND SWEEP
2.20.1 Sweep Append Procedure
2.20.2 IEEE-488 Bus Operation
2.21 MODIFY SWEEP
2.21.1 Sweep Modification Procedure
2.21.2 IEEE-488 Operation
2.22 CONFIGURE TRIGGERS
2.22.1 Input Triggers
2.22.2 Input Trigger Origin
2.22.3 Output Triggers
2.22.4 Sweep End Output Trigger
2.22.5 Enable/Disable Triggers
2.22.6 Trigger Configuration Procedure
2.22.7 IEEE-488 Operation
2.23 PERFORMING A SWEEP
2.24 RECALLING SWEEP DATA
2.25 MULTI UNIT OPERATION

Sweep Operation

Operation Overview

The basic steps to perform a sweep are as follows:

1. Use create to define the parameters of the desired waveform (paragraph 2.19).
2. If needed, use append and/or modify to alter the basic sweep waveform (paragraphs 2.20 and 2.21).
3. Configure the triggers. Triggers are used to start and control a sweep (paragraph 2.22).

Paragraph 2.23 (Performing a Sweep) summarizes the fundamentals of performing a sweep. This short procedure ties together information previously presented in this section (Section 2).

After a sweep is run, test data is stored in the sweep buffer. Recalling data from the sweep buffer is explained in paragraph 2.24.

The Source Measure Unit becomes a more powerful tool when combined with one or more additional Source Measure Units for more complex test systems (such as semiconductor characterization). Mult-unit operation is covered in paragraph 2.25.

2.18 BASIC SWEEP WAVEFORMS

The six basic sweep waveforms that are available are described as follows:

Fixed Level Sweep: As shown in Figure 2-31, this sweep sources a fixed dc level. The programmable parameters of this sweep include; bias, source level, delay, number of measurement points, and source range.

When this sweep is triggered to start, the output will go from the bias level to the source level. The duration of this sweep is determined by the number of measurement points (1 to 1000), the time period of the delay and the measurement time. Notice that a delay precedes every measurement. After the last measurement, the output will return to the bias level.

Linear Staircase Sweep: As shown in Figure 2-32, this sweep steps from a start source value to an ending source value. The programmable parameters of this sweep include; start level, stop level, step, delay, bias, and source range.

When this sweep is triggered to start, the output will go from the bias level to the start source level. The output will then change in equal steps until the stop source level is reached. The time duration at each step of the sweep is largely determined by the programmed delay. A measurement occurs after the delay on each step. After taking the last measurement at the stop source level, the output returns to the bias level.

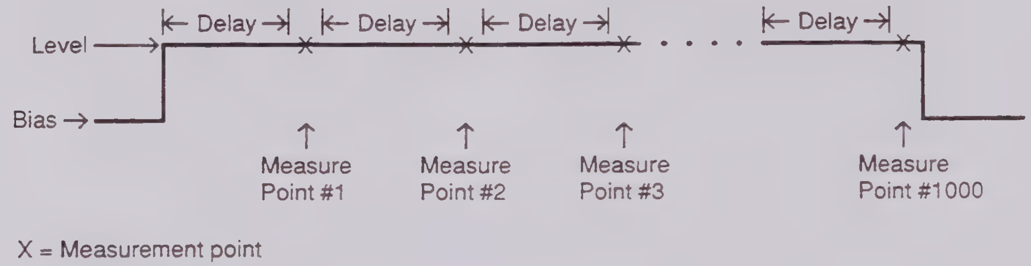

Delay
Delay
Delay
Delay
Level
Bias
Measure Point #1
Measure Point #2
Measure Point #3
Measure Point #1000
X = Measurement point

Figure 2-31. Fixed Level Waveform

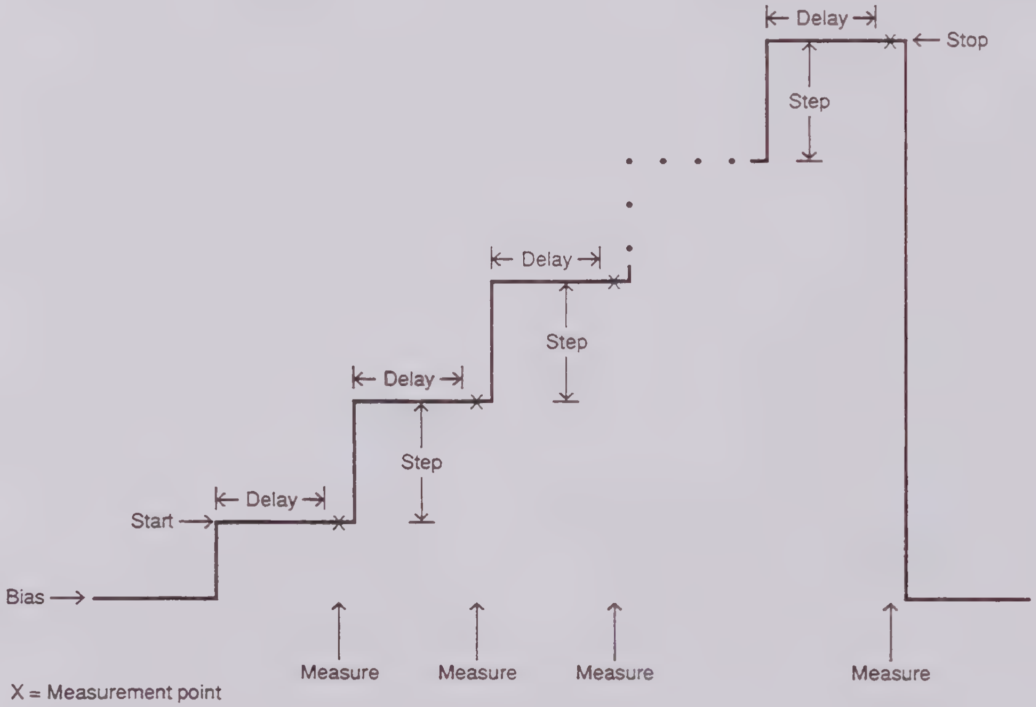

Delay
Stop
Step
Delay
Step
Delay
Step
Delay
Start
Bias
Measure
Measure
Measure
Measure
X = Measurement point

Figure 2-32. Linear Staircase Waveform

Logarithmic Staircase Sweep: This sweep is similar to the preceding staircase sweep, however the steps are done on a logarithmic scale as shown in the example sweep in Figure 2-33. The programmable parameters of this sweep include; start level, stop level, and measure points per decade, delay, bias, and source range.

When this sweep is triggered to start, the output will go from the bias level to the start source level. The start level and the programmed points/decade (5, 10, 25 or 50) determine the step values for the staircase. The Source Measure Unit will automatically select step values that will provide symmetrical steps (on log scale) through each source decade to the stop source level. The sweep example in Figure 2-33 is programmed for 5 points/decade. Thus, the Source Measure Unit selects step values that provide a five-step staircase through each of the two source decades.

The time duration at each step of the sweep is largely determined by the programmed delay. A measurement occurs after the delay on each step. After taking the last

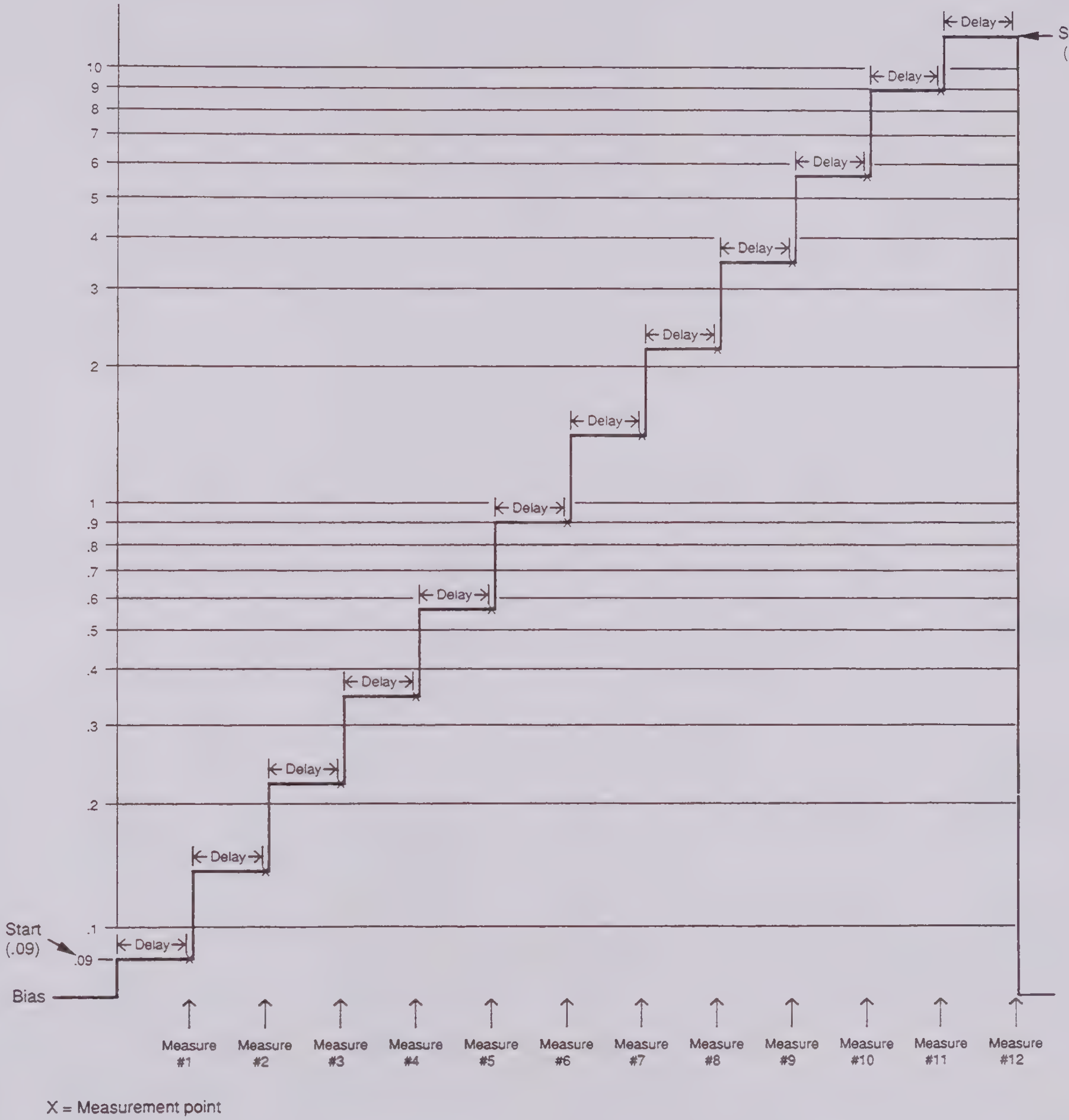

Delay
Stop
(11)
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
Start
(.09)
.09
Bias
Measure #1
Measure #2
Measure #3
Measure #4
Measure #5
Measure #6
Measure #7
Measure #8
Measure #9
Measure #10
Measure #11
Measure #12
X = Measurement point

Figure 2-33. Logarithmic Staircase Waveform (Example Sweep from .09 to 11 at 5pts/decade)

measurement at the stop source level, the output returns to the bias level.

Pulse Sweep: As shown in Figure 2-34, this sweep will output from one to 500 pulses. The programmable parameters of this sweep include; pulse level, number of pulses, pulse on time, pulse off time, bias, and source range.

When this sweep is triggered to start, the output will go from the bias level to the "on" level of the first pulse. The time duration at each pulse level is determined by the programmed "on" time. The time duration at the bias

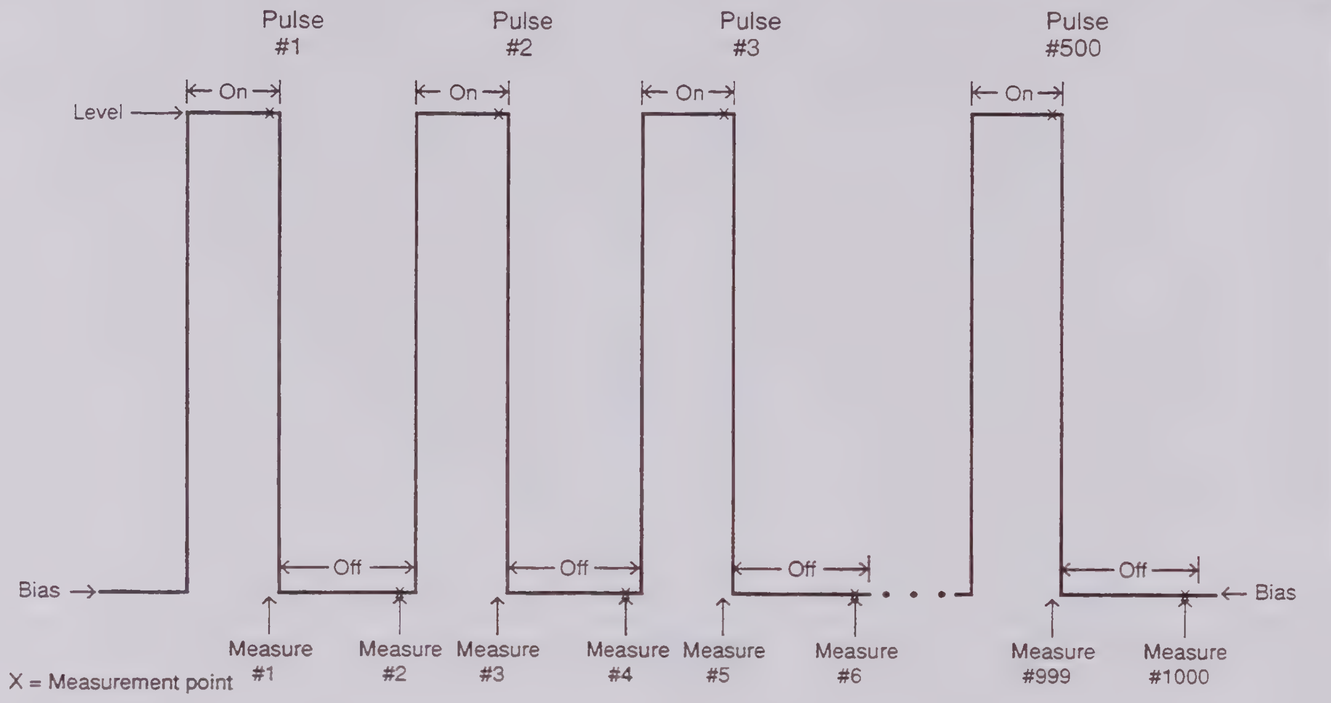


Figure 2-34. Pulse Waveform

level is determined by the off time. Notice that there are two measurements for each pulse; one at the "on" level and one at the following bias ("off") level.

Linear Staircase Pulse Sweep: As shown in Figure 2-35, this pulse sweep steps from a starting pulse level to an ending (stop) pulse level. The programmable parameters of this sweep include; start pulse level, stop pulse level, step, pulse on time, pulse off time, bias, and source range.

When this sweep is triggered to start, the output will immediately go from the bias level to the "on" level of the first pulse. Subsequent pulse levels will be incremented (or decremented) by the step value until the stop pulse level is reached. The time duration at each pulse level is determined by the on time. The time duration at the bias level, is determined by the off time. Notice that there are two measurements for each pulse; one at the "on" level and one at the following bias ("off") level.

Logarithmic Staircase Pulse Sweep: This sweep is similar to the preceding pulse staircase sweep, however the steps are done on a logarithmic scale as shown in the example sweep in Figure 2-36. The programmable parameters of this sweep include; start pulse level, stop pulse level, number of pulses per decade, pulse on time, pulse off time, bias, and source range.

When this sweep is triggered to start, the output will go from the bias level to the start source level. The start level and the programmed points/decade (5, 10, 25 or 50) determine the step values for the staircase. The Source Measure Unit will automatically select step values that will provide symmetrical steps (on log scale) through each source decade to the stop source level. The sweep example in Figure 2-36 is programmed for 5 points/decade. Thus, the Source Measure Unit selects step values that provide a five-step staircase through the source decade.

The time duration at each pulse level is determined by the programmed "on" time. The time duration at the bias level, is determined by the "off" time. Notice that there are two measurements for each pulse; one at the "on" level and one at the following bias ("off") level.

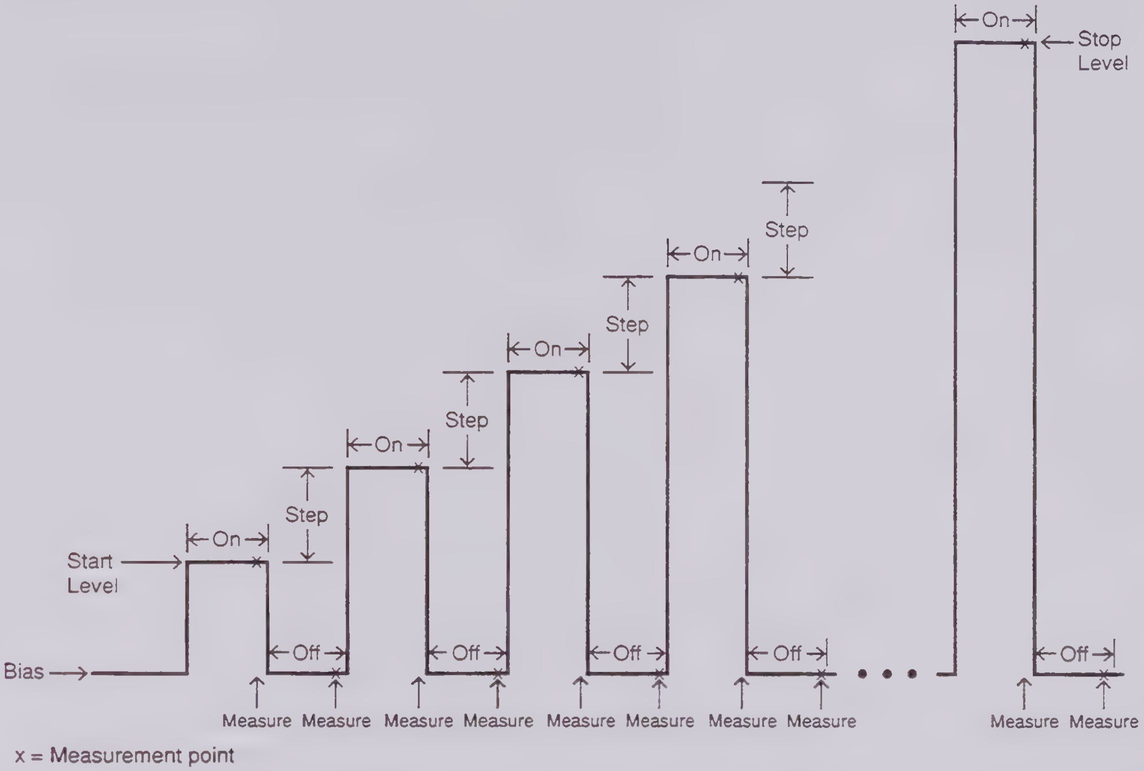

On
Stop Level
Step
On
Step
On
Step
On
Step
On
Start Level
Off
Off
Off
Off
Off
Bias
Measure
Measure
Measure
Measure
Measure
Measure
Measure
Measure
Measure
Measure
x = Measurement point

Figure 2-35. Linear Staircase Pulse Waveform

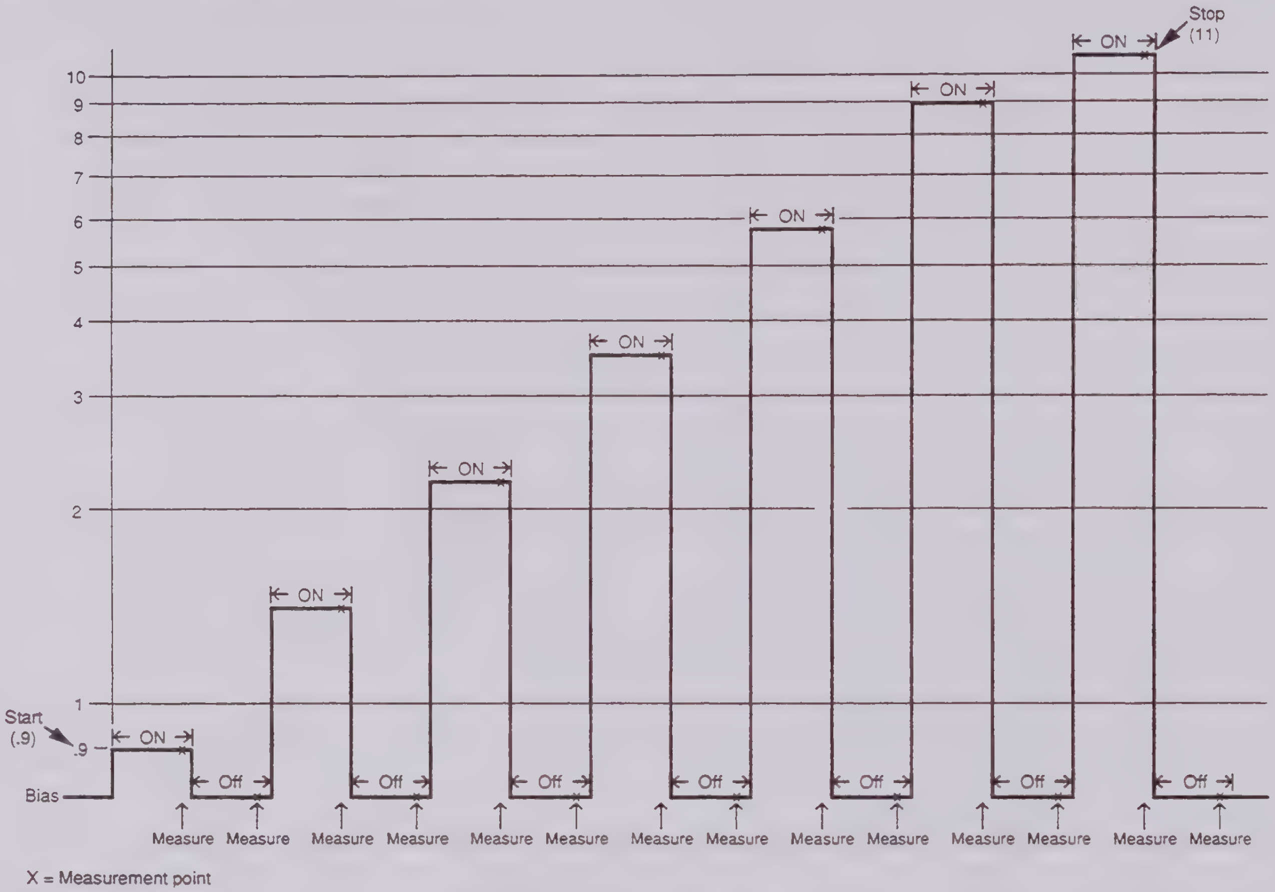

Stop
(11)
10
9
8
7
6
5
4
3
2
1
Start
(.9)
.9
Bias
ON
Off
Measure
X = Measurement point

Figure 2-36. Logarithmic Staircase Pulse Waveform (Example Sweep from .9 to 11 at 5 pts/Decade)

2.19 CREATE SWEEP

The following paragraphs contain the information needed to create a sweep for a selected waveform. Information is organized as follows:

2.19.1 Parameter Definitions: Explains and defines the various sweep parameters that are used.

2.19.2 General Procedure: Provides the general procedure for creating a sweep.

2.19.3 IEEE-488 Bus Operation: Covers the basics needed to create a sweep over the IEEE-488 bus.

> NOTE
>
> The following outlined paragraphs provide detailed step-by-step procedures for creating a sweep for all the available waveforms. For many users, the abbreviated information in paragraph 2.19.2 (general procedure) is sufficient.

2.19.4 Fixed Level Sweep: Provides the detailed procedure for creating a fixed level sweep.

2.19.5 Linear Staircase Sweep: Provides the detailed procedure for creating a linear staircase sweep.

2.19.6 Logarithmic Staircase Sweep: Provides the detailed procedure for creating a logarithmic staircase sweep.

2.19.7 Pulse Sweep: Provides the detailed procedure for creating a pulse sweep.

2.19.8 Linear Staircase Pulse Sweep: Provides the detailed procedure for creating a linear staircase pulse sweep.

2.19.9 Logarithmic Staircase Pulse Sweep: Provides the detailed procedure for creating a logarithmic staircase pulse sweep.

2.19.1 Parameter Definitions

The various programmable sweep parameters are defined as follows:

Bias: Bias is the dc level that is maintained at the output (operate enabled) when a sweep is not in progress. Also, during pulse sweeps, the output goes to the bias level during off time periods (see Figure 2-34 through Figure 2-36). The programmable bias level is from zero to ± maximum source output.

Delay: This is the delay time set by the user for fixed level, linear staircase, and log staircase waveforms. At the end of each programmed delay a measurement is made. Delay can be programmed from 00.000sec to 65.000sec. Delay is also known as sweep delay and user-programmed delay.

Note that the user programmed delay alone does not account for the entire time length of the source-delay-measure cycle. Other factors, such as default delay, range change delays and the measurement integration time add to the overall time of the sweep (see paragraph 3.7.3).

Level: Level is simply the source level for fixed level sweep and pulse sweep waveforms.

No. Points: This is the number of measurements made (1 to 1000) during a fixed level sweep, and the number of pulses (1 to 500) during a pulse sweep. Also known as "count" and "pulses" for IEEE-488 operation.

On and Off Time: On and off times are used for all pulse sweeps. On time is the time duration at each pulse level. Off time is the time duration at the bias level. On and off time can be programmed from 0.001sec to 65.000sec. For IEEE-488 operation, on and off times are known as t_{ON} and t_{OFF}.

The on and off times for a pulse sweep define the entire period of each pulse waveform. The on and off times include the effects of integration rate, filter, and default delay. When a pulse sweep waveform is created, the Source Measure Unit will calculate the delay times needed to satisfy the programmed on and off times of each pulse. The calculated delay times are then stored in the sweep buffer. These delay times can be acquired by examining the sweep buffer (see paragraph 2.24).

If the Source Measure Unit is configured such that it cannot run fast enough to output pulses at the programmed on and off times, the message "PULSE TIME NOT MET" will be displayed. The sweep can be performed, but it will not conform to the programmed on and off times. Speed can be increased by using a faster integration rate, less filtering, and by disabling default delay. Note that the "PULSE TIME NOT MET" message is displayed whenever AUTORANGE is enabled. This indicates that on and off times will most likely not be met when a measure range change occurs. To ensure exact pulses, disable AUTORANGE.

Points/Decade: The points per decade parameter is used for logarithmic sweeps. The number of points (5, 10, 25 or 50) dictate the number of steps and measurements that will occur in a source decade. The actual values of the steps are also dependent on the start value of the staircase sweep. The Source Measure Unit automatically calculates the step values so that a symmetrical staircase (on log scale) will occur through the source decades.

Range: Available source ranges for sweeps include AUTO, BEST FIXED, and the individual fixed ranges. With AUTO range selected, the Source Measure Unit will always go the lowest possible source range while the sweep is in progress. With BEST FIXED range selected, the Source Measure Unit will select the range that will accommodate the largest source level before the sweep is triggered to start. The Source Measure Unit will stay on this range throughout the entire sweep. By avoiding source range changes, overall speed is improved. The user, of course, can select any available fixed source range. However, if the selected range cannot accommodate a source level, the message "VALUE OUT OF RANGE" will be briefly displayed when saving sweep parameters, and range will default to BEST FIXED. Note that source AUTO range cannot be selected for the pulse sweep waveforms.

If a sweep is created using a fixed source range, the "BEST FIXED RANGE" will always be displayed as the range parameter when CREATE is enabled. If a new sweep is not created (CREATE disabled), the sweep will use the previously selected fixed source range.

Start and Stop: All staircase sweeps use start and stop parameters. The staircase begins at the start level and steps to the stop level. In all cases, the output returns to the bias level after the stop level is measured.

Step: The step parameter is used for the linear staircase and linear staircase pulse sweeps. Step is the value that each subsequent source level or pulse increments or decrements in the staircase.

2.19.2 General Procedure

The general procedure for defining a sweep is provided by the following procedure. For many users, this information is enough to define any of the available sweep waveforms. Others may wish to utilize the detailed step-by-step procedures provided in paragraphs 2.19.4 through 2.19.9.

Referring to the appropriate sweep waveform (Figure 2-31 through Figure 2-36), perform the following steps to define the parameters of a sweep.

Step 1. Select Source

To sweep (source) voltage, the Source Measure Unit must be in Source V Measure I. Conversely, to sweep (source) current, the Source Measure Unit must be in Source I Measure V.

Step 2. Enable Sweep CREATE

The currently defined sweep waveform will be displayed. If you wish to define a different sweep waveform, proceed to step 3.

The parameters of the displayed sweep waveform can be displayed by using the rotary knob. If you are going use this sweep as it is currently defined, press CREATE and then ENTER. The Source Measure Unit will return to the source-measure display state. To change one or more parameters of this sweep waveform, proceed to step 4.

Step 3. Select Sweep Waveform

Figure 2-37 shows the sweep waveform selections. Use the SELECT buttons to display the desired sweep waveform and then press ENTER.

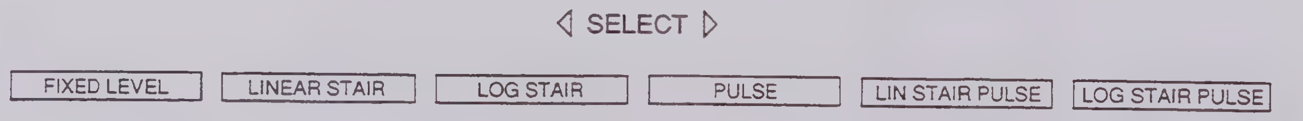


Figure 2-37. Sweep Waveform Selections

Step 4. Define Sweep Parameters

The parameter sweep lists for all the available sweep waveforms are provided in Figure 2-38 through Figure 2-43. Any parameter of the sweep can be displayed using the rotary knob. Changes to all parameters, except points/decade and range, are accomplished by using the keypad to key-in the value and pressing ENTER. Changes to the points/decade and range parameters are accomplished using the SELECT buttons to display the parameter option and pressing ENTER.

When a parameter value is entered (ENTER pressed), the next parameter of the sweep is displayed. Note that when the last parameter (range) is changed (SELECT pressed), the other sweep parameters cannot be displayed with the rotary knob. When a range parameter is entered (ENTER pressed), the Source Measure Unit exits the sweep list and prompts the user to save or cancel the sweep parameters.

Step 5. Save Sweep Parameters

In order to save sweep parameters, the message "SAVE? ENTER/CANCEL" must be displayed. This message is displayed after the range parameter is entered. It can also be displayed by again pressing CREATE.

With "SAVE? ENTER/CANCEL" displayed, press ENTER to save the sweep parameters. The GENERATING SWEEP message will be displayed. Pressing CANCEL will default the sweep to the previously programmed definition.

NOTES

1. The maximum number of measure points in a sweep is 1000. If a sweep is defined such that it exceeds 1000 points, the message "BUFFER FILLED" will be displayed briefly when the sweep is saved. The sweep will default to 1000 points.
2. When a sweep is saved (step 5), all data stored in the buffer from the previous sweep is lost.
3. The on and off times for a pulse sweep define the entire period of each pulse waveform. The on and off times include the effects of integration rate, filter, and default delay. If the Source Measure Unit is configured such that it cannot run fast enough to output pulses at the programmed on and off times, the message "PULSE TIME NOT MET" will be displayed. The sweep can be performed, but it will not conform to the programmed on and off times. Speed can be increased by using a faster integration rate, less filtering, and by disabling default delay. Note that the message "PULSE TIME NOT MET" is always displayed when AUTORANGE is enabled (see paragraph 2.13).
4. A log sweep cannot start at 0 or sweep through 0. If a sweep is programmed to start at 0, it will default to one count on the selected source range. If programmed to sweep through 0, the message "LOG CANNOT CROSS 0" will be displayed when trying to save the parameters. The sweep will be cancelled.
5. Entering a STEP value that is less than the resolution of the source range will default to a step value of zero. The source will never exceed the level of the first sweep point. The maximum STEP value is twice the full scale range of the highest range used in generating the sweep.
6. Changing a parameter value (or source range) of the currently saved sweep also affects the parameters of the other sweep waveforms for the selected source (V or I). For example, setting the voltage sweep delay

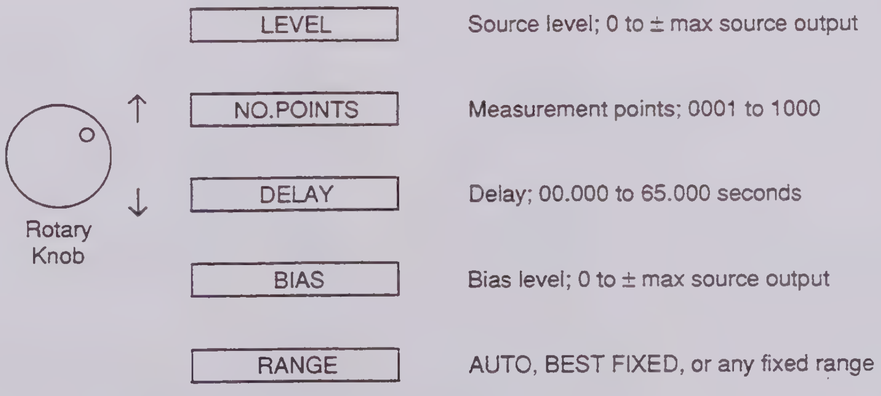
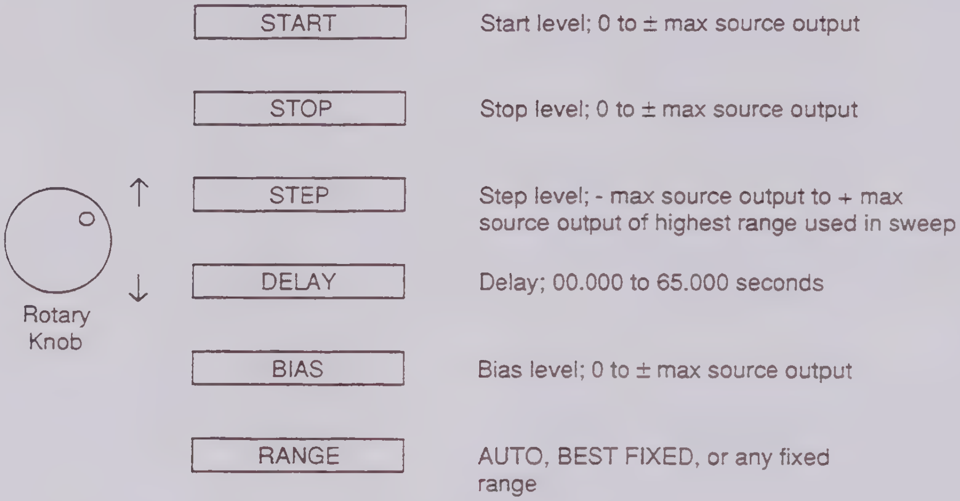
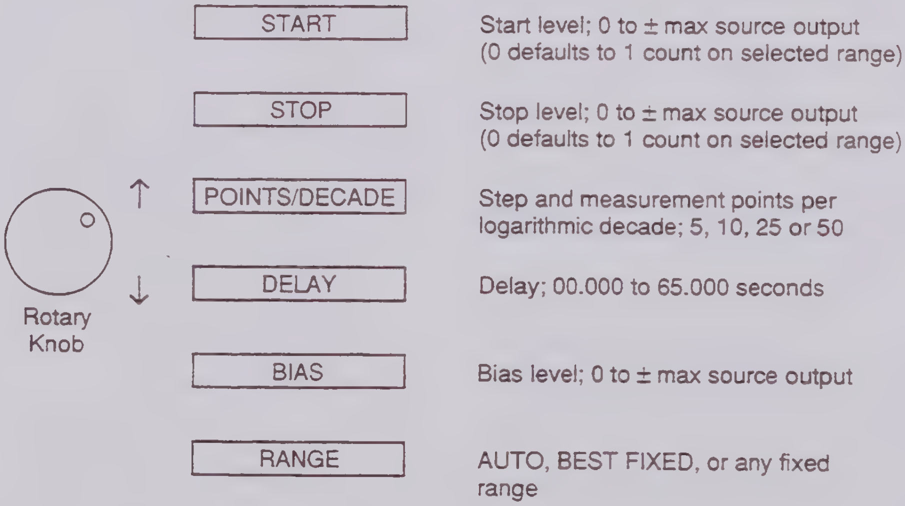

LEVEL
Source level; 0 to ± max source output
NO.POINTS
Measurement points; 0001 to 1000
DELAY
Delay; 00.000 to 65.000 seconds
Rotary Knob
BIAS
Bias level; 0 to ± max source output
RANGE
AUTO, BEST FIXED, or any fixed range

Figure 2-38. Fixed Level Sweep Parameters



START	Start level; 0 to ± max source output
STOP	Stop level; 0 to ± max source output
STEP	Step level; - max source output to + max source output of highest range used in sweep
DELAY	Delay; 00.000 to 65.000 seconds
BIAS	Bias level; 0 to ± max source output
RANGE	AUTO, BEST FIXED, or any fixed range

Figure 2-39. Linear Staircase Sweep Parameters

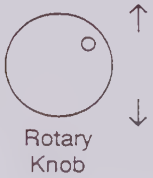


START	Start level; 0 to ± max source output (0 defaults to 1 count on selected range)
STOP	Stop level; 0 to ± max source output (0 defaults to 1 count on selected range)
POINTS/DECADE	Step and measurement points per logarithmic decade; 5, 10, 25 or 50
DELAY	Delay; 00.000 to 65.000 seconds
BIAS	Bias level; 0 to ± max source output
RANGE	AUTO, BEST FIXED, or any fixed range

Figure 2-40. Logarithmic Staircase Sweep Parameters

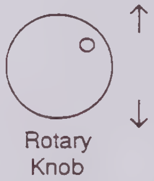
to one second also sets the delay parameter of the other voltage sweep waveforms to one second.

7. Changing the "level" of a sweep waveform also changes the "start" value of the other sweep waveforms of the selected source. Conversely, changing the "start" value also changes the "level" of the other sweep waveforms for the selected source.
8. Cycling power will not affect the last created sweep. If a sweep was run, the data (measurements and ΔT), will be retained in the buffer.
9. Performing factory initialization will clear the sweep buffer. The last created sweep will be cancelled. Sweep parameters return to the factory default conditions.



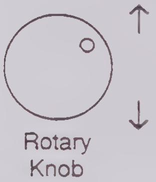
LEVEL	Pulse level; 0 to ± max source output
NO. POINTS	No. of pulses; 001 to 500
ON TIME	Pulse on time (at source level) ; 00.001 to 65.000 seconds
OFF TIME	Pulse off time (at bias level) ; 00.001 to 65.000 seconds
BIAS	Bias level; 0 to ± max source output
RANGE	BEST FIXED or any fixed range

Figure 2-41. Pulse Sweep Parameters



START	Level of first pulse; 0 to ± max source output
STOP	Level of last pulse; 0 to ± max source output
STEP	Step level; - max source output to + max source output of highest range used in sweep
ON TIME	Pulse on time (at source level) ; 00.001 to 65.000 seconds
OFF TIME	Pulse off time (at bias level) ; 00.001 to 65.000 seconds
BIAS	Bias level; 0 to ± max source output
RANGE	BEST FIXED or any fixed range

Figure 2-42. Linear Staircase Pulse Sweep Parameters



START	Level of first pulse; 0 to ± max source output (0 defaults to 1 count on selected range)
STOP	Level of last pulse; 0 to ± max source output (0 defaults to 1 count on selected range)
POINTS/DECADE	No. of pulse and measurement points per logarithmic decade; 5, 10, 25 or 50
ON TIME	Pulse on time (at source level) ; 00.001 to 65.000 seconds
OFF TIME	Pulse off time (at bias level) ; 00.001 to 65.000 seconds
BIAS	Bias level; 0 to ± max source output
RANGE	BEST FIXED or any fixed range

Figure 2-43. Logarithmic Staircase Pulse Sweep Parameters

2.19.3 IEEE-488 Bus Operation

The Q command is used to create (and append) a sweep for a selected waveform.

Q0,(level),(range),(delay),(count)	Fixed level sweep
Q1,(start),(stop),(step),(range),(delay)	Linear staircase sweep
Q2,(start),(stop),(points),(range),(delay)	Log staircase sweep
Q3,(level),(range),(pulses),(t_{ON}),(t_{OFF})	Pulse sweep
Q4,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})	Linear staircase pulse sweep
Q5,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})	Log staircase pulse sweep

The parameter values used for level, start, stop, and step that are sent with the appropriate Q command are similar to the values entered from the front panel (see Figure 2-38 through Figure 2-43). The IEEE parameters that deviate from front panel parameters are explained as follows:

Count — Number of points in a fixed level sweep (0001 to 1000).

Delay, t_{ON}, t_{OFF} — Time parameters are expressed in milliseconds (0 - 65000).

Points — Logarithmic points per decade:

0 = 5 points/decade
1 = 10 points/decade
2 = 25 points/decade
3 = 50 points/decade

Range — Source range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option

Note: The Q commands to append a sweep list (Q6 through Q11) are explained in paragraph 2.20.

The bias level for a sweep is established with the B command as follows:

B(level),(range),(delay)

The delay parameter only applies to dc operation. During sweep operation, this parameter is ignored. To simplify programming, the delay parameter can be left out as follows:

B(level),(range),

Notice that the comma after the range parameter must be included. The following programming example shows how this command is sent.

HP BASIC 4.0 Programming Example:

The following program will create a sweep list for the linear staircase sweep.

```
10   REMOTE 716
20   OUTPUT 716; "F0,1X"         Source V Measure I
                                 (sweep)
30   OUTPUT 716; "B0,0,X"        Set bias level to 0V
40   OUTPUT 716;                 Create lin stair sweep
     "Q1,1,10,1,0,500X"           list
50   END
```

The above program will create a sweep list for the linear staircase sweep waveform. The staircase will be programmed to start at 1V and step in 1V increments up to 10V. The programmed dwell on each step is 1/2 second.

Complete information on the IEEE-488 bus and these commands can be found in Section 3 of this manual.

2.19.4 Fixed Level Sweep

Perform the following steps to create a sweep list for a fixed level sweep waveform (see Figure 2-31):

1. Select the desired source (Source I Measure V, or Source V Measure I).
2. Enable sweep create.
3. Use the SELECT buttons to display the fixed level sweep (as shown below).

FIXED LEVEL

4. Press ENTER. The last programmed source level will be displayed. For example, if the last programmed source level was 1V, the following would be displayed:

+1.0000 V LEVEL

5. To change the source value, key-in the value using the keypad (edit method; see paragraph 2.9.1). For example, the following shows a keyed-in value of 2.5V.

+2.5 VOLTS

6. Press ENTER. The number of measurement points in the fixed sweep will be displayed. For example if the last programmed number of points was 10, the following will be displayed:

0010 NO. POINTS

7. To change the number of measurement points (0001 to 1000), key-in the value using the keypad. The following shows a keyed-in value of 20 points:

20 NO. POINTS

Note: Entering a value that exceeds 1000 will simply default to 1000.

8. Press ENTER. The delay will then be displayed. If the delay is presently set to 1/2 second, the following will be displayed:

00.500 SEC DELAY

9. To change the time delay (00.000 to 65.000 seconds), key-in the value using the keypad. The following shows a keyed-in value of 1 second:

1 SECONDS

10. Press ENTER. The bias level will then be displayed. For example, if the bias is presently set to 0V, the following will be displayed:

+0.0000 V BIAS

11. To change the bias level, key-in the value from the keypad. The following shows a keyed-in bias level of −1.25V:

−1.25 VOLTS

12. Press ENTER. The currently selected source range will be displayed. For example, if autorange is currently selected, the following will be displayed:

AUTO RANGE

13. To change the source range, use the SELECT buttons to display the desired range. The following shows the 11V range selected:

11.000V RANGE

Note: Selecting a fixed range that is lower than the keyed-in level or bias value will result in the message "VALUE OUT OF RANGE" when the parameters are saved. In this situation, the source will default to BEST FIXED range.

14. Press ENTER. The following message will be displayed:

SAVE? ENTER/CANCEL

15. At this point, the keyed-in parameters can be entered (saved), or canceled. Perform one of the following steps:
    A. To enter and save the keyed-in parameters, press ENTER. The GENERATING SWEEP message will be displayed. Sweep create will disable and the Source Measure Unit will return to the source-measure display state.
    B. To cancel the keyed-in parameters, press CANCEL. Sweep create will disable and the Source Measure Unit will return to the source-measure display state. The previously programmed sweep parameters will prevail.

2.19.5 Linear Staircase Sweep

Perform the following steps to create a sweep list for a linear staircase sweep waveform (see Figure 2-32):

1. Select the desired source (Source I Measure V, or Source V Measure I).
2. Enable sweep create.
3. Use the SELECT buttons to display the linear staircase sweep (as shown below).

LINEAR STAIR

4. Press ENTER. The last programmed source start value will be displayed. For example, if the last programmed start value was 1V, the following would be displayed:

   +1.0000 V   START

5. To change the source value, key-in the value using the keypad (edit method; see paragraph 2.9.1). For example, the following shows a keyed-in value of 2.5V.

   +2.5   VOLTS

6. Press ENTER. The source level at which the sweep will STOP is displayed. For example if the last programmed stop value is 10V, the following will be displayed:

   +10.000 V   STOP

7. To change the stop value, key-in the value using the keypad. The following shows a keyed-in value of 20V:

   +20   VOLTS

   Note: Entering a stop or step value that will result in more than 1000 measure points will cause the message "BUFFER FILLED" to be briefly displayed when the sweep is saved. When the sweep is run, it will stop after the 1000th measure point instead of after the programmed stop level.

8. Press ENTER. The step value will then be displayed. If, for example, the step is presently 1V, the following will be displayed:

   +1.0000   STEP

9. To change the step, key-in the value using the keypad. The following shows a keyed-in value of 2V:

   +2   VOLTS

   Note: Entering a step value that is lower than the resolution of the source range will result with the message "VALUE OUT OF RANGE" when the parameters are saved. A step value of zero will be used. The source will never exceed the level of the first sweep point.

   Note: The maximum step value is twice the full scale range of the highest range used in generating the sweep.

10. Press ENTER. The delay will then be displayed. If the delay is presently set to 1/2 second, the following will be displayed:

    00.500 SEC   DELAY

11. To change the time delay (00.000 to 65.000 seconds), key-in the value using the keypad. The following shows a keyed-in value of one second:

    1   SECONDS

12. Press ENTER. The bias level will then be displayed. For example, if the bias is presently set to 0V, the following will be displayed:

    +0.0000 V   BIAS

13. To change the bias level, key-in the value from the keypad. The following shows a keyed-in bias level of –1.25V:

    –1.25   VOLTS

14. Press ENTER. The currently selected source range will be displayed. For example, if autorange is currently selected, the following will be displayed:

    AUTO   RANGE

15. To change the source range, use the SELECT buttons to display the desired range. The following shows the 11V range selected:

    11.000V   RANGE

    Note: Selecting a fixed range that is lower than the highest keyed-in source value will result in the message "VALUE OUT OF RANGE" when the parameters are saved. In this situation, the source will default to BEST FIXED range.

16. Press ENTER. The following message will be displayed:

    SAVE? ENTER/CANCEL

17. At this point, the keyed-in parameters can be entered and saved, or canceled. Perform one of the following steps:
    A. To enter and save the keyed-in parameters, press ENTER. The GENERATING SWEEP message

will be displayed. Sweep create will disable and the Source Measure Unit will return to the source-measure display state.

B. To cancel the keyed-in parameters, press CANCEL. Sweep create will disable and the Source Measure Unit will return to the source-measure display state. The previously programmed sweep parameters will prevail.

2.19.6 Logarithmic Staircase Sweep

Perform the following steps to create a sweep for a logarithmic staircase waveform (see Figure 2-33):

1. Select the desired source (Source I Measure V, or Source V Measure I).
2. Enable sweep create.
3. Use the SELECT buttons to display the log staircase sweep (as shown below).

   LOG STAIR

4. Press ENTER. The last programmed source start value will be displayed. For example, if the last programmed start value was 1V, the following would be displayed:

   +1.0000 V START

5. To change the source value, key-in the value using the keypad (edit method; see paragraph 2.9.1). For example, the following shows a keyed-in value of 2.5V.

   +2.5 VOLTS

6. Press ENTER. The source level at which the sweep will STOP is displayed. For example if the last programmed stop value is 100V, the following will be displayed:

   +100.00 V STOP

7. To change the stop value, key-in the value using the keypad. The following shows a keyed-in value of 20V:

   +20 VOLTS

8. Press ENTER. POINTS/DECADE will then be displayed. If, for example, five source-measure points per decade is currently selected, the following will be displayed:

   5 POINTS/DECADE

9. To select an alternate points per decade value (5, 10, 25 or 50), use the SELECT buttons to display the desired value. The following shows a selection of 50 source-measure points per decade:

   50 POINTS/DECADE

10. Press ENTER. The delay will then be displayed. If the delay is presently set to 1/2 second, the following will be displayed:

    00.500 SEC DELAY

11. To change the time delay (00.001 to 65.000 seconds), key-in the value using the keypad. The following shows a keyed-in value of one second:

    1 SECONDS

12. Press ENTER. The bias level will then be displayed. For example, if the bias is presently set to 0V, the following will be displayed:

    +0.0000 V BIAS

13. To change the bias level, key-in the value from the keypad. The following shows a keyed-in bias level of –1.25V:

    –1.25 VOLTS

14. Press ENTER. The currently selected source range will be displayed. For example, if autorange is currently selected, the following will be displayed:

    AUTO RANGE

15. To change the source range, use the SELECT buttons to display the desired range. The following shows the 11V range selected:

    11.000V RANGE

    Note: Selecting a fixed range that is lower than the highest keyed-in source or bias value will result in the message "VALUE OUT OF RANGE" when the parameters are saved. In this situation, the source will default to BEST FIXED range.

16. Press ENTER. The following message will be displayed:

    SAVE? ENTER/CANCEL

17. At this point, the keyed-in parameters can be entered and saved, or canceled. Perform one of the following steps:
    A. To enter and save the keyed-in parameters, press ENTER. The GENERATING SWEEP message will be displayed. Sweep create will disable and the Source Measure Unit will return to the source-measure display state.
    B. To cancel the keyed-in parameters, press CANCEL. Sweep create will disable and the Source Measure Unit will return to the source-measure display state. The previously programmed sweep parameters will prevail.

NOTE

A log sweep cannot start at 0 or sweep through 0. If a sweep is programmed to start at 0, it will default to 1 count on the present source range. If programmed to sweep through 0, the message "LOG CANNOT CROSS 0" will be displayed when trying to save the parameters. The sweep will be cancelled.

2.19.7 Pulse Sweep

Perform the following steps to create a sweep for a pulse waveform (see Figure 2-34):

1. Select the desired source (Source I Measure V, or Source V Measure I) and disable autorange (measure) if it is enabled.
2. Enable sweep create.
3. Use the SELECT buttons to display the pulse sweep (as shown below).

PULSE

4. Press ENTER. The last programmed pulse level will be displayed. For example, if the last programmed pulse level was 1V, the following would be displayed:

+1.0000 V LEVEL

5. To change the source value, key-in the value using the keypad (edit method; see paragraph 2.9.1). For example, the following shows a keyed-in value of 2.5V.

+2.5 VOLTS

6. Press ENTER. The number of pulses in the sweep will be displayed. For example, if the last programmed number of pulses is 10, the following will be displayed:

0010 NO. POINTS

7. To change the number of pulses (0001 to 0500), key-in the value using the keypad. The following shows a keyed-in value of 20 points:

20 NO. POINTS

Note: Entering a value that exceeds 500 will simply default to 500. When the sweep is saved, the message "BUFFER FILLED" will be displayed briefly to indicate you tried to enter a value that exceeded 500.

8. Press ENTER. The pulse on time will then be displayed. If the on time is presently set to 100msec, the following will be displayed:

00.100 SEC ON TIME

9. To change the on time (00.001 to 65.000 seconds), key-in the value using the keypad. The following shows a keyed-in value of 200msec:

+.2 SECONDS

10. Press ENTER. The programmed off time will be displayed. For example, if the off time is presently 1/2 second, the following will be displayed:

00.500 SEC OFF TIME

11. To change the off time, key-in the time value using the keypad. The following shows a keyed-in value of 300msec:

+.3 SECONDS

12. Press ENTER. The bias level will then be displayed. For example, if the bias is presently set to 0V, the following will be displayed:

+0.0000 V BIAS

13. To change the bias level, key-in the value from the keypad. The following shows a keyed-in bias level of –1.25V:

–1.25 VOLTS

14. Press ENTER. The currently selected source range will be displayed. For example, if 110V range is currently selected, the following will be displayed:

110.00V RANGE

15. To change the source range, use the SELECT buttons to display the desired range. The following shows the 11V range selected:

    11.000V RANGE

    Note: Selecting a fixed range that is lower than the highest keyed-in source or bias value will result in the message "VALUE OUT OF RANGE" when the parameters are saved. In this situation, the source will default to BEST FIXED range.

16. Press ENTER. The following message will be displayed:

    SAVE? ENTER/CANCEL

17. At this point, the keyed-in parameters can be entered and saved, or canceled. Perform one of the following steps:
    A. To enter and save the keyed-in parameters, press ENTER. The GENERATING SWEEP message will be displayed. Sweep create will disable and the Source Measure Unit will return to the source-measure display state.
    B. To cancel the keyed-in parameters, press CANCEL. Sweep create will disable and the Source Measure Unit will return to the source-measure display state. The previously programmed sweep parameters will prevail.

NOTE

The on and off times for a pulse sweep define the entire period of each pulse waveform. The on and off times include the effects of integration rate, filter, and default delay. If the Source Measure Unit is configured such that it cannot run fast enough to output pulses at the programmed on and off times, the message "PULSE TIME NOT MET" will be displayed. The sweep can be performed, but it will not conform to the programmed on and off times. Speed can be increased by using a faster integration rate, less filtering, and by disabling default delay. Note that the message "PULSE TIME NOT MET" is always displayed when AUTORANGE is enabled (see paragraph 2.13).

2.19.8 Linear Staircase Pulse Sweep

Perform the following steps to create a sweep for a linear staircase pulse waveform (see Figure 2-35):

1. Select the desired source (Source I Measure V, or Source V Measure I) and disable autorange (measure) if it is enabled.
2. Enable sweep create.
3. Use the SELECT buttons to display the linear staircase pulse sweep (as shown below).

   LIN STAIR PULSE

4. Press ENTER. The source level of the first pulse (START) will be displayed. For example, if the level of the first pulse is currently set at 1V, the following will be displayed:

   +1.0000 START

5. To change the start level, key-in the value using the keypad. A keyed-in value of 2V is shown as follows:

   +2 VOLTS

6. Press ENTER. The source level of the last pulse in the sweep (STOP) will be displayed. For example, if the stop level is currently at 20V, the following will be displayed;

   +020.00 V STOP

7. To change the stop value, key-in the level using the keypad. A keyed-in value of 50V is shown as follows:

   +50 VOLTS

   Note: Entering a stop value that will result in more than 500 pulses (1000 measurements) will cause the message "BUFFER FILLED" to be briefly displayed when the sweep is saved. When the sweep is run, it will stop after the 500th pulse measure point instead of after the programmed stop level.

8. Press ENTER. The staircase step value will be displayed. For example, if the step value is currently set to 1V, the following will be displayed:

   +1.0000 V STEP

9. To change the step value, key-in the value using the keypad. The following shows a keyed-in step value of 2V:

+2 VOLTS

Note: Entering a step value that is lower than the resolution of the source range will result with the message "VALUE OUT OF RANGE" when the parameters are saved. A step value of zero will be used. The source will never exceed the level of the first sweep point.

Note: The maximum step value is twice the full scale range of the highest range used in generating the sweep.

10. Press ENTER. The pulse on time will then be displayed. If the on time is presently set to 100msec, the following will be displayed:

    00.100 SEC ON TIME

11. To change the pulse on time (00.001 to 65.000 seconds), key-in the value using the keypad. The following shows a keyed-in value of 200msec:

    +.2 SECONDS

12. Press ENTER. The programmed off time will be displayed. For example, if the off time is presently 1/2 second, the following will be displayed:

    00.500 SEC OFF TIME

13. To change the off time, key-in the time value using the keypad. The following shows a keyed-in value of 300msec:

    +.3 SECONDS

14. Press ENTER. The bias level will then be displayed. For example, if the bias is presently set to 0V, the following will be displayed:

    +0.0000 V BIAS

15. To change the bias level, key-in the value from the keypad. The following shows a keyed-in bias level of –1.25V:

    –1.25 VOLTS

16. Press ENTER. The currently selected source range will be displayed. For example, if 110V range currently selected, the following will be displayed:

    110.00V RANGE

17. To change the source range, use the SELECT buttons to display the desired range. The following shows the 11V range selected:

    11.000V RANGE

    NOTE: Selecting a fixed range that is lower than the highest keyed-in source or bias value will result in the message "VALUE OUT OF RANGE" when the parameters are saved. In this situation, the source will default to BEST FIXED range.

18. Press ENTER. The following message will be displayed:

    SAVE? ENTER/CANCEL

19. At this point, the keyed-in parameters can be entered and saved, or canceled. Perform one of the following steps:
    A. To enter and save the keyed-in parameters, press ENTER. The GENERATING SWEEP message will be displayed. Sweep create will disable and the Source Measure Unit will return to the source-measure display state.
    B. To cancel the keyed-in parameters, press CANCEL. Sweep create will disable and the Source Measure Unit will return to the source-measure display state. The previously programmed sweep parameters will prevail.

NOTE

The on and off times for a pulse sweep define the entire period of each pulse waveform. The on and off times include the effects of integration rate, filter, and default delay. If the Source Measure Unit is configured such that it cannot run fast enough to output pulses at the programmed on and off times, the message "PULSE TIME NOT MET" will be displayed. The sweep can be performed, but it will not conform to the programmed on and off times. Speed can be increased by using a faster integration rate, less filtering, and by disabling default delay. Note that the message "PULSE TIME NOT MET" is always displayed when AUTORANGE is enabled (see paragraph 2.13).

2.19.9 Log Staircase Pulse Sweep

Perform the following steps to create a sweep for a logarithmic staircase pulse waveform (see Figure 2-36):

1. Select the desired source (Source I Measure V, or Source V Measure I) and disable AUTORANGE (measure) if it is enabled.
2. Enable sweep create.
3. Use the SELECT buttons to display the log staircase pulse sweep (as shown below).

LOG STAIR PULSE

4. Press ENTER. The source level of the first pulse (start) will be displayed. For example, if the level of the first pulse is currently set at 1V, the following will be displayed:

+1.0000 V START

5. To change the start level, key-in the value using the keypad. A keyed-in value of 2V is shown as follows:

+2 VOLTS

6. Press ENTER. The source level of the last pulse in the sweep (stop) will be displayed. For example, if the stop level is currently at 20V, the following will be displayed;

+020.00 V STOP

7. To change the stop value, key-in the level using the keypad. A keyed-in value of 50V is shown as follows:

+50 VOLTS

8. Press ENTER. POINTS/DECADE will then be displayed. If, for example, five source-measure points per decade is currently selected, the following will be displayed:

5 POINTS/DECADE

9. To select an alternate points per decade value (5, 10, 25 or 50), use the SELECT buttons to display the desired value. The following shows a selection of 50 source-measure points per decade:

50 POINTS/DECADE

10. Press ENTER. The pulse on time will then be displayed. If the on time is presently set to 100msec, the following will be displayed:

00.100 SEC ON TIME

11. To change the pulse on time (00.001 to 65.000 seconds), key-in the value using the keypad. The following shows a keyed-in value of 200msec:

+.2 SECONDS

12. Press ENTER. The programmed off time will be displayed. For example, if the off time is presently 1/2 second, the following will be displayed:

00.500 SEC OFF TIME

13. To change the off time, key-in the time value using the keypad. The following shows a keyed-in value of 300msec:

+.3 SECONDS

14. Press ENTER. The bias level will then be displayed. For example, if the bias is presently set to 0V, the following will be displayed:

+0.0000 V BIAS

15. To change the bias level, key-in the value from the keypad. The following shows a keyed-in bias level of –1.25V:

–1.25 VOLTS

16. Press ENTER. The currently selected source range will be displayed. For example, if 110V range is currently selected, the following will be displayed:

110.00V RANGE

17. To change the source range, use the SELECT buttons to display the desired range. The following shows the 11V range selected:

11.000V RANGE

Note: Selecting a fixed range that is lower than the highest keyed-in source or bias value will result in the error message "VALUE OUT OF RANGE" when the parameters are saved. In this situation, the source will default to BEST FIXED range.

18. Press ENTER. The following message will be displayed:

SAVE? ENTER/CANCEL

19. At this point, the keyed-in parameters can be entered and saved, or canceled. Perform one of the following steps:

A. To enter and save the keyed-in parameters, press ENTER. The GENERATING SWEEP message will be displayed. Sweep create will disable and the Source Measure Unit will return to the source-measure display state.
B. To cancel the keyed-in parameters, press CANCEL. Sweep create will disable and the Source Measure Unit will return to the source-measure display state. The previously programmed sweep parameters will prevail.

NOTES:

1. The on and off times for a pulse sweep define the entire period of each pulse waveform. The on and off times include the effects of integration rate, filter, and default delay. If the Source Measure Unit is configured such that it cannot run fast enough to output pulses at the programmed on and off times, the message "PULSE TIME NOT MET" will be displayed. The sweep can be performed, but it will not conform to the programmed on and off times. Speed can be increased by using a faster integration rate, less filtering, and by disabling default delay. Note that the message "PULSE TIME NOT MET" is always displayed when AUTORANGE is enabled (see paragraph 2.13).
2. A log sweep cannot start at 0 or sweep through 0. If a sweep is programmed to start at 0, it will default to 1 count on the present source range. If programmed to sweep through 0, the message "LOG CANNOT CROSS 0" will be displayed when trying to save the parameters. The sweep will be cancelled.

2.20 APPEND SWEEP

The append feature permits one or more waveforms to be appended to the currently defined sweep waveform. The waveforms that can be appended to sweep waveforms are listed in Table 2-11. The number of waveforms that can be appended to a defined sweep is limited only by the total number of points (1000).

You cannot append to a sweep that does not exist. Trying to do so will cause the message "MUST CREATE SWEEP" to be displayed.

Table 2-11. APPEND Waveform

Defined Sweep Waveform	Available APPEND Sweep Waveforms
Fixed level	Fixed level Linear staircase Log staircase
Linear staircase	Fixed level Linear staircase Log staircase
Log staircase	Fixed level Linear staircase Log staircase
Pulse	Pulse Linear staircase pulse Log staircase pulse
Linear staircase pulse	Pulse Linear staircase pulse Log staircase pulse
Log staircase pulse	Pulse Linear staircase pulse Log staircase pulse

An example of an appended sweep is shown in Figure 2-44. Fixed level sweep #1 is appended with a linear staircase waveform and another fixed level waveform. The original fixed level sweep sources a constant 1V level for five measurement points. After the last measurement of the fixed level sweep, the staircase sweep starts at 2V and staircases (in 1V steps) to 6V. After the measurement at the 6V step, another fixed level sweep sources 2V for five more measurement points.

Whenever the integration rate, filter or default delay is changed, the Source Measure Unit will re-calculate the delay needed to satisfy the programmed on and off times of a pulse waveform. If an appended pulse waveform uses different on and off times than the original pulse waveform, any subsequent delay calculations will be based on the on and off times of the appended pulse waveform. The on and off times of the original pulse waveform will default to the on and off times of the appended pulse waveform. Thus, DO NOT change integration rate, filter, default delay, or range after appending a pulse waveform that uses different on and off times. Always configure these features before appending a pulse sweep.

An appended sweep can be customized further with the use of the sweep MODIFY feature (see paragraph 2.21).

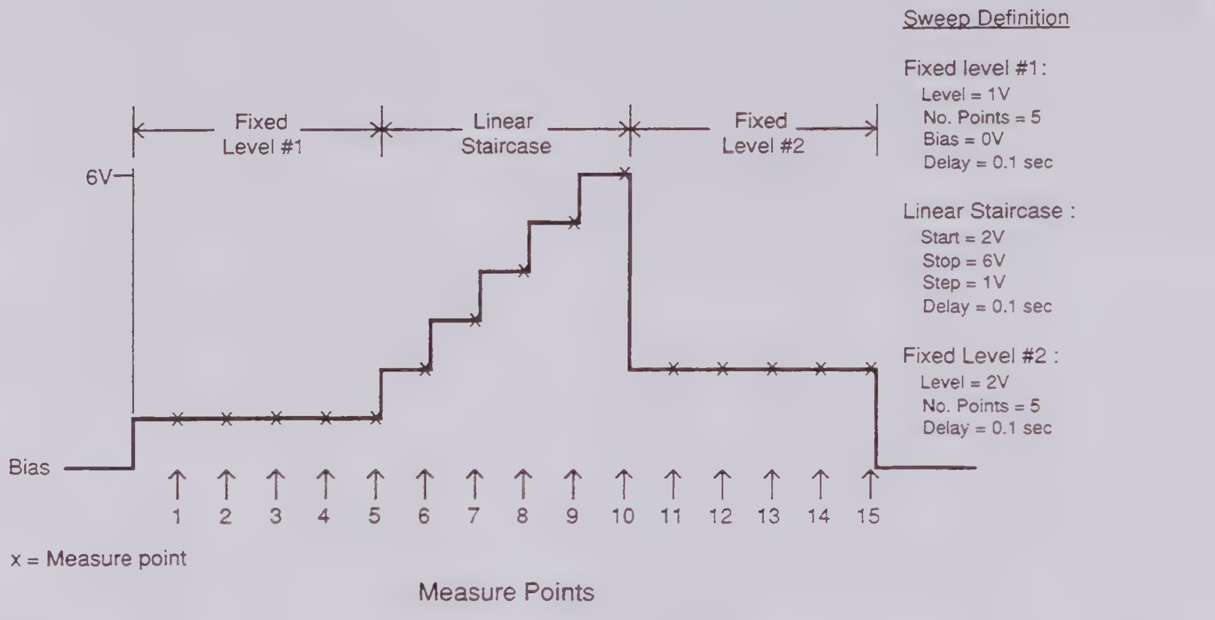

Sweep Definition
Fixed level #1:
Level = 1V
No. Points = 5
Bias = 0V
Delay = 0.1 sec
Linear Staircase :
Start = 2V
Stop = 6V
Step = 1V
Delay = 0.1 sec
Fixed Level #2 :
Level = 2V
No. Points = 5
Delay = 0.1 sec
Fixed Level #1
Linear Staircase
Fixed Level #2
6V
Bias
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
x = Measure point
Measure Points

Figure 2-44. Sweep Append Example

General Append Rules:

1. Enabling APPEND displays the currently defined sweep waveform.
2. An alternate append waveform (see Table 2-11) can be selected by displaying it with the SELECT buttons and pressing ENTER.
3. The parameters of a selected append waveform can be displayed with the rotary knob.
4. A displayed parameter can be changed with the keypad or the SELECT buttons and then by pressing ENTER.
5. An appended waveform is saved when ENTER is pressed with the message "SAVE? ENTER/CANCEL" displayed. That message is displayed when APPEND is pressed or when a displayed range parameter is ENTERed.

2.20.1 Sweep Append Procedure

Perform the following steps to append the currently defined sweep waveform with another sweep waveform:

Step 1. Enable Sweep APPEND

The same type of sweep that is already defined will be displayed. For example, if the fixed level sweep is currently defined, the following will be displayed when sweep append is enabled:

FIXED LEVEL

If appending the defined sweep with the same (displayed) sweep type, proceed to step 3.

Step 2. Select Sweep Type

Use the SELECT buttons to display the sweep type that you wish to append to the already defined sweep and press ENTER.

Step 3. Define Sweep Parameters

These sweep parameters are entered in the same way that parameters were entered for the original sweep.

Any parameter of the sweep can be displayed using the rotary knob. Changes to all parameters, except points/decade and range, are accomplished by using the keypad to key-in the value and pressing ENTER. Changes to the points/decade and range parameters are accomplished by using the SELECT buttons to display the parameter option and pressing ENTER.

When a parameter value is entered (ENTER pressed), the next parameter of the sweep is displayed. Note that when the last parameter (range) is changed (SELECT pressed), the other sweep parameters cannot be displayed with the rotary knob. When a range parameter is entered (ENTER pressed), the Source Measure Unit exits the sweep menu and prompts the user to save or cancel the sweep parameters.

Step 4. Save Sweep Parameters

In order to save sweep parameters, the message "SAVE? ENTER/CANCEL" must be displayed. This message is displayed when the range parameter is entered. It can also be displayed by again pressing APPEND.

With "SAVE? ENTER/CANCEL" displayed, press ENTER to save the sweep parameters. The GENERATING SWEEP message will be displayed. Pressing CANCEL will cancel the append operation. Only the original sweep waveform will be defined.

NOTES:

1. Sweep APPEND can only be enabled if the Source Measure Unit is in the source-measure display state.
2. If the total number of measure points in a sweep exceeds 1000, the message "BUFFER FILLED" will be briefly displayed when the sweep parameters are saved. The sweep will default to 1000 measure points.
3. Bias is the only parameter that cannot be defined in an APPEND sweep. The bias level that was defined in the original sweep will prevail.
4. A non-existent sweep cannot be appended.
5. After appending a sweep, RECALL can be used to look at all points of the sweep.
6. After appending a sweep, enabling CREATE will display only the parameters of the appended portion of the sweep.

2.20.2 IEEE-488 Bus Operation

The Q command is used to append a sweep list for a selected sweep waveform.

Q6,(level),(range),(delay),(count)	Fixed level sweep
Q7,(start),(stop),(step),(range), (delay)	Linear staircase sweep
Q8,(start),(stop),(points),(range), (delay)	Log staircase sweep
Q9,(level),(range),(pulses),(t_{ON}), (t_{OFF})	Pulse sweep
Q10,(start),(stop),(step),(range), (t_{ON}),(t_{OFF})	Linear staircase pulse sweep
Q11,(start),(stop),(points),(range), (t_{ON}),(t_{OFF})	Log staircase pulse sweep

The parameter values used for level, start, stop and step, that are sent with the appropriate Q command, are similar to the values entered from the front panel (see Figure 2-38 through Figure 2-43). The IEEE parameters that deviate from front panel parameters are explained as follows:

Count — Number of points in a fixed level sweep (0001 to 1000).

Delay, t_{ON}, t_{OFF} — Time parameters are expressed in milliseconds (0 - 65000).

Points — Logarithmic points per decade:

0 = 5 points/decade
1 = 10 points/decade
2 = 25 points/decade
3 = 50 points/decade

Range — Source range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option

NOTE:

The Q commands to create a sweep list (Q0 through Q5) are explained in paragraph 2.19.3.

HP BASIC 4.0 Programming Example:

The following program will append a fixed level sweep to a staircase sweep.

```
10   REMOTE 716
20   OUTPUT 716; "F0,1X"        Source V Measure I
                                (sweep)
30   OUTPUT 716; "B0,0,X"       Set bias level to 0V
40   OUTPUT 716;                Create lin stair sweep
     "Q1,1,10,1,0,500X"         list
50   OUTPUT 716;                Append a fixed level
     "Q6,2,0,300,5X"            sweep
60   END
```

Lines 10 through 40 create a sweep list for the linear staircase sweep waveform. The staircase will start at 1V and step in 1V increments up to 10V. The programmed dwell on each step is 1/2 second. Line 50 will append a fixed level (2V, 5 points, and 300msec delay) sweep to the staircase sweep.

Complete information on the IEEE-488 bus and these commands can be found in Section 3 of this manual.

2.21 MODIFY SWEEP

The modify feature permits source level and delay time changes to be made for any measurement point in the currently defined sweep. This feature allows custom shaped waveforms to be fabricated.

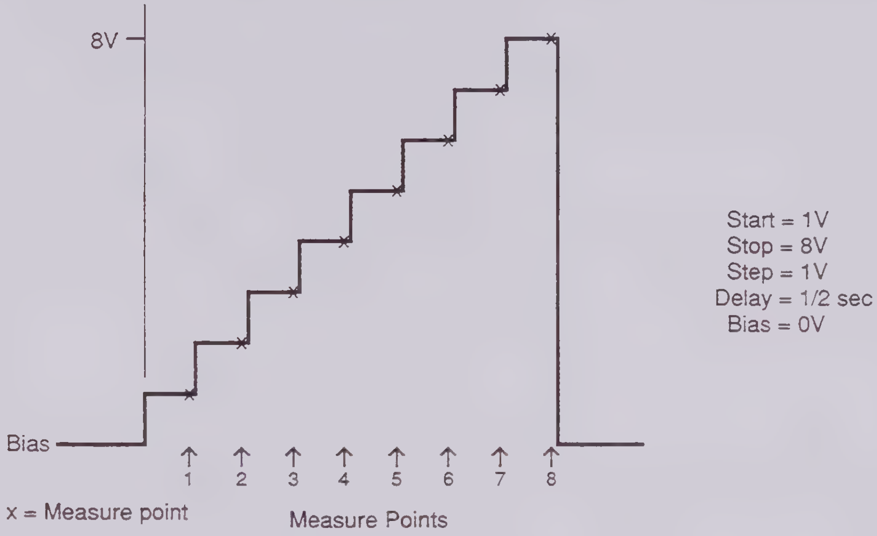
An example of a modified sweep is shown in Figure 2-45. The linear staircase sweep waveform is modified as shown to demonstrate the versatility of the modify feature. The first four measure points of the staircase are unchanged. The fifth point is changed to the same level as the fourth point (4V). The result is a staircase step that has more than one measure point. This allows multiple measurements to be performed on a single step of a staircase waveform. The rest of the sweep (points 6, 7 and 8) is modified to step down to the bias level using a longer dwell time on the steps.

General Modify Rules:

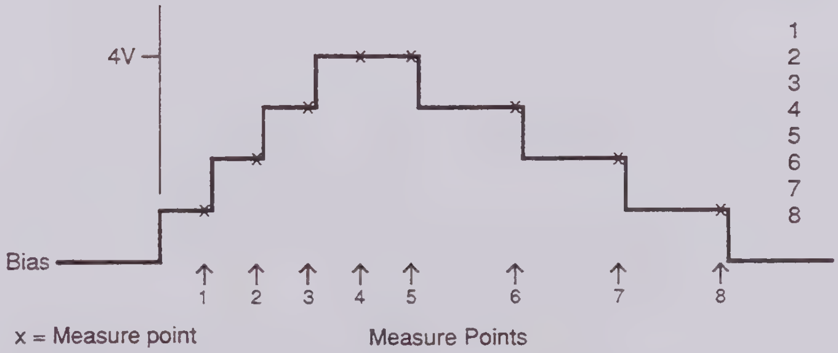
1. Enabling MODIFY displays the source value of the first sweep point. Any sweep point can be displayed with the rotary knob. SELECT ▶ and ◀ SELECT toggles the display between the source and delay parameter for the displayed sweep point.
2. A source value is modified as follows:
   - A. Using the rotary knob, display the sweep point to be modified.
   - B. Using the keypad, key in the new source value and press ENTER.
   - C. Using the SELECT buttons, display the desired source range and press ENTER.
3. A delay period is modified as follows:
   - A. Using the rotary knob, display the sweep point to be modified.
   - B. Using the keypad, key in the new delay period and press ENTER.
4. Exit the modify menu by again pressing MODIFY.

In many test situations, only minor modifications to a sweep waveform that is already being used will be required. Complex waveform fabrication will require a little more planning. The following hints may be helpful:

1. Sketch the waveform that you wish to fabricate. Indicate source levels, measure points and delay times.
2. Select and define (CREATE) a standard sweep waveform that will be the easiest to modify into your custom waveform.
3. Consider the value of appending one or more waveforms to the one you just defined (see Append Sweep; paragraph 2.20).
4. With a good fundamental waveform defined, go ahead and modify it as follows.



A. Linear Staircase Sweep



Point	Source	Delay
1	1V	0.5 S
2	2V	0.5 S
3	3V	0.5 S
4	4V	0.5 S
5	4V	0.5 S
6	3V	1 S
7	2V	1 S
8	1V	1 S

B. Modified Linear Staircase

Figure 2-45. Sweep Modify Example

2.21.1 Sweep Modification Procedure

Perform the following steps to modify the currently defined sweep waveform:

Step 1. Enable Sweep MODIFY.

The source level at the first measure point will be displayed. For example, if the source level at the first point is 1V, the following will be displayed:

0001 +1.0000 V SRC

Step 2. Modify Source Levels

The rotary knob will display the source level for each measure point in the sweep. To change a source level, perform the following steps:

1. Use the rotary knob to display the measure point whose source level is to be changed.
2. Key-in the new source level from the keypad.
3. Press ENTER. The source range for the original source level will be displayed. For example, if in autorange, the following will be displayed:

   AUTO RANGE

4. If an alternate source range is needed or desired, use the SELECT buttons to display it. Note that the source range must be able to accommodate the new source value.
5. Press ENTER. The newly entered source value will be displayed.
6. Repeat steps 1 through 5 to change the source level at another measure point.

Step 3. Modify Delay Times

If one or more delay times are going to be changed, perform the following steps. Otherwise, proceed to step 4.

1. Press SELECT▶. The delay time for one of the measure points will be displayed as shown in the following example:

   0005 00.500 SEC DLY

2. Use the rotary knob to display the measure point whose delay is to be changed.
3. Key-in the new delay time from the keypad.
4. Press ENTER. The newly entered delay time will be displayed.
5. Repeat steps 1 through 4 to change the delay time at another measure point.

Step 4. Exit Modify State

To return the Source Measure Unit to the normal source-measure display state press either Sweep MODIFY or ENTER.

NOTES:

1. Sweep MODIFY can only be enabled if the Source Measure Unit is in the source-measure display state.
2. A non-existent sweep cannot be modified.

2.21.2 IEEE-488 Operation

Over the IEEE-488 bus, the A command is used to modify a sweep list. When this command is sent, one point or consecutive points can be modified to the specified parameters.

A(level),(range),(delay),(first),(last)

With this command, the level, range and delay period are established for the point(s) specified by the "first" and "last" parameters.

Range — Source range:

	I-source	**V-source**
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option

Delay — Programmed in milliseconds (0 to 65000).

First — First data point to be modified.

Last — Last data point to be modified.

HP BASIC 4.0 Programming Example:

The following program will modify a fixed level sweep.

```
10   REMOTE 716
20   OUTPUT 716; "F0,1X"        Source V Measure I
                                (sweep)
30   OUTPUT 716; "B0,0,X"       Set bias to 0V
40   OUTPUT 716;                Create fixed level
     "Q0,1,0,500,10X"           sweep
50   OUTPUT 716;                Modify point 1
     "A2,0,500,1,1X"
60   OUTPUT 716;                Modify points 4, 5 and 6
     "A3,0,1000,4,6X"
70   END
```

Lines 10 through 40 create a fixed level sweep (1V, 1/2 second delay, 10 measure points). Line 50 modifies point 1 to 2V. Line 60 modifies points 4, 5 and 6 to 3V with a delay of one second.

Complete information on the IEEE-488 bus and this command can be found in Section 3 of this manual.

2.22 CONFIGURE TRIGGERS

Source Measure Unit operation consists of a series of source-delay-measure (SDM) cycles. In dc operation, the Source Measure Unit will continuously execute SDM cycles (see Figure 2-46). In sweep operation, the number of SDM cycles that make up the sweep waveform is defined by the user. Figure 2-47A shows a five-point fixed level sweep waveform. For a staircase sweep, an SDM cycle occurs at every step of the staircase as shown in Figure 2-47B. For a pulse sweep, an SDM cycle occurs at each pulse on level and bias off level as shown in Figure 2-47C.

The available trigger setups are shown in Figure 2-48.

Input triggers are used to control when source, delay, and measure operations occur. The input (IN) triggers are described in paragraph 2.22.1.

The input trigger stimulus may be provided by the front panel MANUAL trigger button, an external device that applies a TTL level pulse to the TRIGGER IN connector on the rear panel, or an appropriate IEEE-488 operation. Input trigger origin is described in paragraph 2.22.2.

The Source Measure Unit is capable of sending TTL level output pulses (via its TRIGGER OUT connector) to trigger operations of external devices, such as another Source Measure Unit. The Source Measure Unit can be programmed to output a trigger after any phase of the SDM cycle. Output (OUT) triggers are described in paragraph 2.22.3.

In addition to the previously mentioned output triggers, the Source Measure Unit can also be programmed to output a trigger pulse at the end of a sweep. The sweep end output trigger setup is described in paragraph 2.22.4.

Finally, input and output triggers of the Source Measure Unit can be be disabled by the enable/disable triggers setup which is described in paragraph 2.22.5.

The procedure to configure the triggers is provided in paragraph 2.22.6. Programming the trigger over the IEEE-488 bus is covered in paragraph 2.22.7.

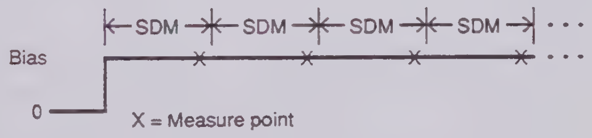
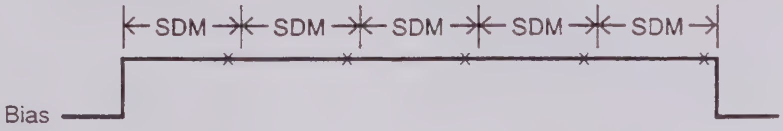
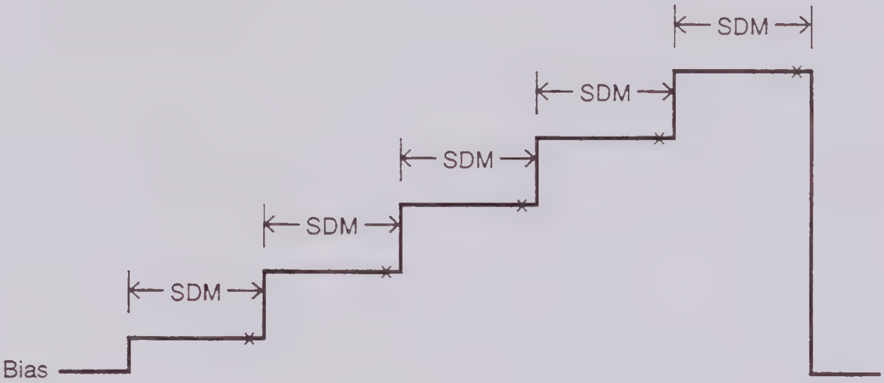


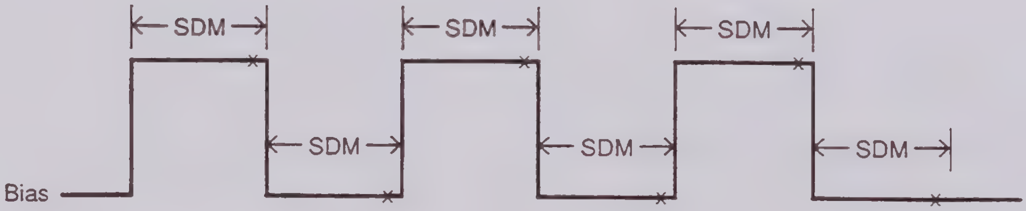
Figure 2-46. SDM Cycles - Dc Operation


SDM
SDM
SDM
SDM
SDM
Bias

A. Fixed Level Sweep Example


SDM
SDM
SDM
SDM
SDM
Bias

B. Staircase Sweep Example


SDM
SDM
SDM
SDM
SDM
SDM
Bias

C. Pulse Sweep Example

X = Measure point

Figure 2-47. SDM Cycles - Sweep Operation

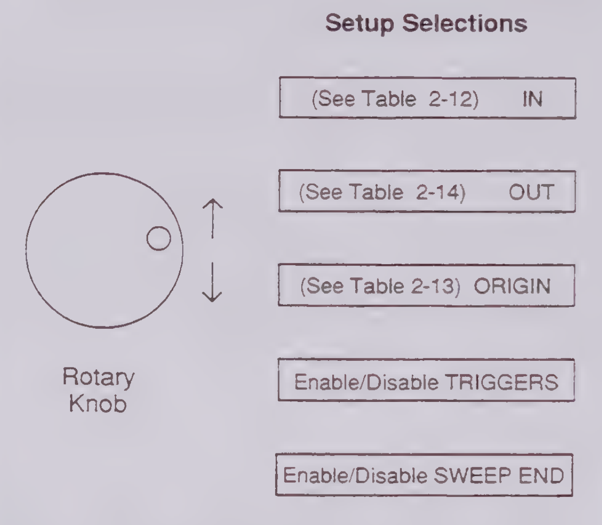


Figure 2-48. Trigger Setups

2.22.1 Input Triggers

There are a variety of input triggers to choose from which are summarized in Table 2-12. Note that most trigger selections use one, two or three pointers (^) to indicate the trigger occurrence. For example:

^SRC DLY MSR IN

For this selection, a trigger will cause a single source, delay and measurement (one SDM cycle) to occur. The Source Measure Unit will then pause and wait for another trigger. Another example:

^SRC^DLY MSR IN

For this selection, two triggers are used to process each SDM cycle. The first trigger sets the source level. The Source Measure Unit then pauses and waits for the next trigger. That next trigger initiates a delay and measurement to occur. Again the Source Measure Unit pauses and waits for the another trigger.

Table 2-12. Input Triggers

Trigger Selection		Description
CONTINUOUS	IN	Continuously process all SDM cycles.
^SRC DLY MSR	IN	Each trigger will process an SDM cycle.
SRC^DLY MSR	IN	Initial trigger sets source. Each subsequent trigger initiates a delay and measure, then sets source of next SDM cycle.
^SRC^DLY MSR	IN	Two triggers process each SDM cycle. First trigger sets source. Second trigger initiates a delay and measure.
SRC DLY^MSR	IN	Initial trigger sets source and causes a delay. Second trigger initiates measure, and then, for the next SDM cycle, sets source and initiates a delay.
^SRC DLY^MSR	IN	Two triggers process each SDM cycle. First trigger sets source and initiates a delay. Second trigger initiates a measure.
SRC^DLY^MSR	IN	Initial trigger sets source. Two triggers process each SDM cycle. First trigger initiates a delay. Second trigger initiates a measure and sets source of next SDM cycle.
^SRC^DLY^MSR	IN	Three triggers process each SDM cycle. First trigger sets source. Second trigger initiates a delay. Third trigger initiates a measure.
^SINGLE PULSE	IN	Pulse sweep trigger. Each trigger processes the on time (t_{ON}) and off time (t_{OFF}) of each pulse in the sweep. Two measurements are made for each pulse.

Input Trigger Descriptions:

All of the available input triggers are described as follows:

CONTINUOUS IN

Dc Operation: As long as the MANUAL TRIGGER light is on and not blinking, a trigger is not needed. A continuous series of SDM cycles commence when the the unit is placed in OPERATE. When the MANUAL TRIGGER light is blinking, a trigger is required to start the continuous source-delay-measure process.

Sweep Operation: A single trigger causes the sweep to start and continue until it is complete. In other words, a single trigger causes all SDM cycles in the sweep to be processed.

^SRC DLY MSR IN

Dc Operation: Each trigger processes a single SDM cycle. That is, each trigger causes a source, delay, and measurement to occur.

Sweep Operation: For each SDM cycle of the sweep, a trigger causes a source, delay, and measurement (which is displayed) to occur. After the last measurement of the sweep is made, a following trigger causes the unit to return to the bias level.

SRC^DLY MSR IN

Dc Operation: An initial trigger sets the level of the source. Each subsequent trigger causes a delay and measurement to occur, and re-applies the source level of the next SDM cycle.

Sweep Operation: An initial trigger starts the sweep process by setting the unit to the first source level of the sweep. A measurement is not made at this time. For each SDM cycle of the sweep, a trigger causes a delay and measurement to occur, and sets the unit to the source level of the next SDM cycle. After the last measurement (which is displayed) of the sweep is made, a following trigger causes the unit to return to the bias level.

^SRC^DLY MSR IN

Dc Operation: Each SDM cycle is processed by two triggers. The first trigger sets the source level and the the second trigger causes a delay and measure to occur.

Sweep Operation: Two triggers process each SDM cycle of the sweep. The first trigger sets the source level and the second trigger causes a delay and measurement (which is displayed) to occur. A trigger following the last measurement in the sweep causes the unit to return to the bias level.

SRC DLY^MSR IN

Dc Operation: An initial trigger sets the source level and causes a delay to occur. Each subsequent trigger causes a measurement to occur, and then processes the source and delay phases of the next SDM cycle.

Sweep Operation: An initial trigger starts the sweep process by setting the unit to the first source level and causing a delay to occur. A measurement is not made at this time. For each SDM cycle of the sweep, a trigger causes a measurement to be made. Also, it sets the source level of the next SDM cycle and causes a delay to occur. After the last measurement (which is displayed) in the sweep is made, a following trigger returns the unit to the bias level.

^SRC DLY^MSR IN

Dc Operation: Each SDM cycle is processed by two triggers. The first trigger sets the source level and causes a delay to occur. The second trigger causes a measurement to occur.

Sweep Operation: Two triggers are required to process each SDM cycle of the sweep. The first trigger sets the source level and causes a delay to occur. The second trigger causes a measurement (which is displayed) to occur. A trigger following the last measurement in the sweep will return the unit to the bias level.

SRC^DLY^MSR IN

Dc Operation: An initial trigger sets the level of the source. Each SDM cycle of the sweep is then processed by two triggers. The first trigger causes a delay to occur. The second trigger causes a measurement to occur and re-applies the source level of the next SDM cycle.

Sweep Operation: An initial trigger starts the sweep process by setting the unit to the first source level of the sweep. Two triggers are then required to process each SDM cycle of the sweep. The first trigger causes a delay to occur. The second trigger causes a measurement to occur, and then sets the source level of the next SDM cycle. After the last measurement (which is displayed) in the sweep is made, a following trigger returns the unit to the bias level.

^SRC^DLY^MSR IN

Dc Operation: Three triggers are used to process each SDM cycle. The first trigger sets the source level. The second trigger causes a delay to occur. The third trigger causes a measurement to occur.

Sweep Operation: Three triggers are required to process each SDM cycle of the sweep. The first trigger sets the source level. The second trigger causes the delay to occur. The third trigger causes a measurement to be made and displayed. A trigger after the last measurement in the sweep is made returns the unit to the bias level.

^SINGLE PULSE IN

NOTE

> This trigger is intended to be used only for pulse sweeps. If used for dc operation, the unit will operate in a continuous trigger mode.

Sweep Operation: Each trigger will process the on time (t_{ON}) and off time (t_{OFF}) periods (two SDM cycles) of each pulse in the sweep (see Figure 2-49). If used with a non-pulse sweep, each trigger will process two points.

The single pulse input trigger is often used with the pulse end output trigger (see paragraph 2.22.3 and Figure 2-50).

Input Trigger Notes:

1. A "TRIGGER OVERRUN" error will occur if a trigger occurs while a source, delay or measure is in process. In this event, the invalid trigger will be ignored.
2. Dc operation, single-shot triggers: The following occurrences will cause the measure display to blank (i.e. "—.–mA") indicating that the SDM sequence has been terminated:
   A. Changing the source level.

   WARNING
   A hazardous voltage may be present at the output even if the display indicates otherwise. The displayed source value will not be applied to the output until a trigger occurs. Thus, the previous source level (that may be hazardous) is still on the output.

   B. Enabling/disabling AUTORANGE or SUPPRESS.
   C. Entering an integration time or filter value.
   D. Creating, appending or modifying a sweep.
   E. Selecting a different single-shot trigger.

   Refer to the appropriate input trigger description to restart the SDM sequence.
3. Front panel MANUAL TRIGGER light notes:
   A. A blinking MANUAL TRIGGER light denotes that an input trigger is needed to start the SDM sequence.
   B. The light is on when a trigger response is in process.
   C. The light is off when triggers are disabled (see paragraph 2.22.5).

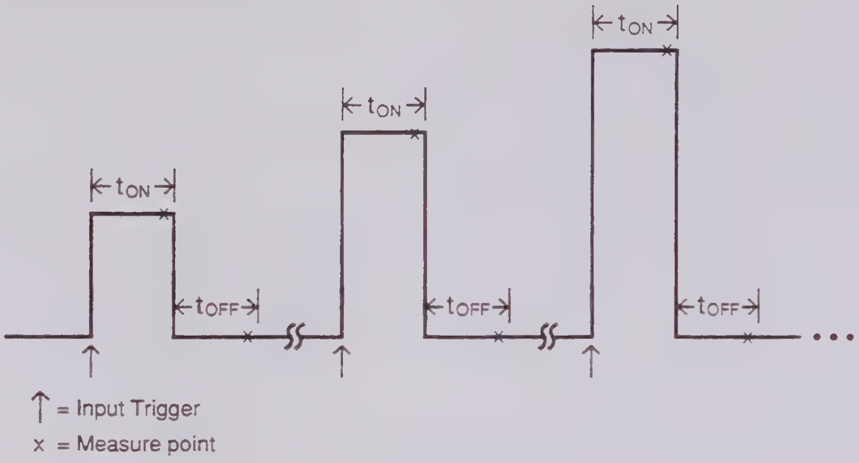

tON
tON
tON
tOFF
tOFF
tOFF
↑ = Input Trigger
x = Measure point

Figure 2-49. Single Pulse Input Trigger

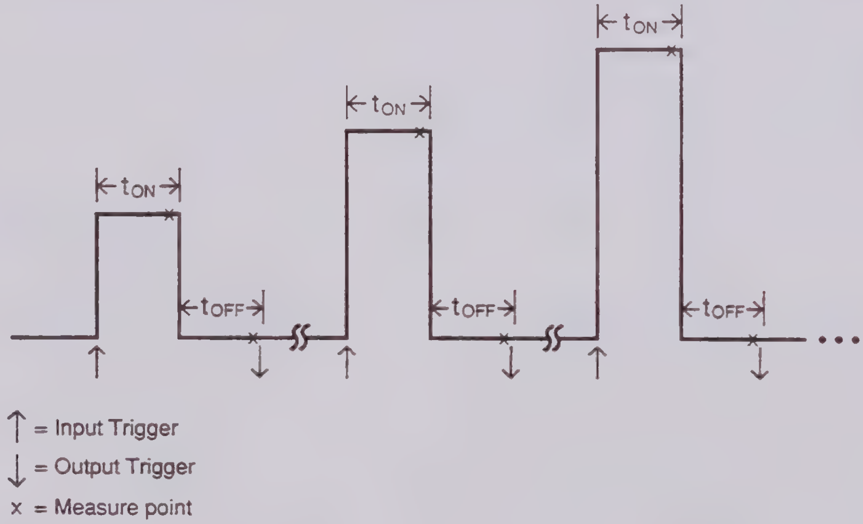

tON
tON
tON
tOFF
tOFF
tOFF
↑ = Input Trigger
↓ = Output Trigger
x = Measure point

Figure 2-50. Using a Single Pulse and Pulse End Trigger Together

2.22.2 Input Trigger Origin

The source (origin) of input triggers is defined by this trigger setup. Input trigger origin selections (summarized in Table 2-13) are described as follows:

Internal Origin

With this trigger origin selected, an input trigger will occur when the front panel MANUAL trigger button is pressed or the H0 command is sent over the IEEE-488 bus.

External Origin

With this trigger origin selected, an input trigger will occur when a TTL level pulse (see Figure 2-51) is applied to the TRIGGER IN connector (BNC) of the Source Measure Unit (see Figure 2-52) by an external instrument. This input trigger will cause the Source Measure Unit to perform one or more operations.

Also, an input trigger will occur when the front panel MANUAL trigger button is pressed or the H0 command is sent over the IEEE-488 bus.

IEEE TALK Origin

With this trigger origin selected, an input trigger will occur when the Source Measure Unit is addressed to talk over the IEEE-488 bus. Also, an input trigger will occur when the H0 command is sent over the IEEE-488 bus, or, if in local operation, when the front panel MANUAL trigger button is pressed. See Section 3 for complete information.

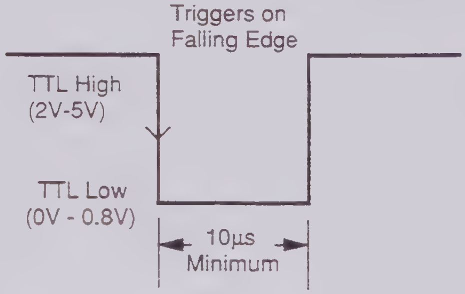


Figure 2-51. External Input Trigger Pulse Specification

IEEE GET Origin

With this trigger origin selected, an input trigger will occur when a group execute trigger (GET) is sent over the IEEE-488 bus. Also, an input trigger will occur when the H0 command is sent over the IEEE-488 bus, or, if in local operation, when the front panel MANUAL trigger button is pressed.

IEEE X Origin

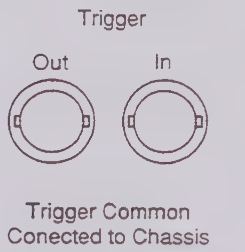
With this trigger origin selected, an input trigger will occur when an "X" is sent over the IEEE-488 bus. Also, an input trigger will occur when the H0 command is sent over the IEEE-488 bus, or, if in local operation, when the front panel MANUAL trigger button is pressed.

Table 2-13. Input Trigger Origin

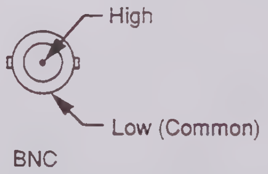
Selection	Trigger Stimulus
INTERNAL ORIGIN	Front panel MANUAL trigger button or H0 command over IEEE-488 bus.
EXTERNAL ORIGIN	Negative-going TTL level pulse applied to TRIGGER IN connector.
IEEE TALK ORIGIN	Unit addressed to talk over IEEE-488 bus.
IEEE GET ORIGIN	Group execute trigger (GET) command sent over IEEE-488 bus.
IEEE X ORIGIN	"X" sent over IEEE-488 bus.

2.22.3 Output Triggers

The Source Measure Unit can be programmed to output one or more trigger pulses at various strategic times during operation. When an output trigger occurs, a negative-going TTL level pulse (see Figure 2-53) is applied to the TRIGGER OUT connector (see Figure 2-52) on the rear panel. An output trigger is used to cause an external instrument to perform one or more operations. Paragraph 2.25 shows how external triggers are used to control a test system that uses two or more Source Measure Units.



A. Trigger Connections



B. Trigger In and Out Connector Configuration

Figure 2-52. Trigger In and Trigger Out Connections

Output triggers are listed and explained in Table 2-14. Notice that for all except the pulse end and sweep end output triggers, one, two or three output triggers occur during each SDM cycle of operation. The pointer (^) indicates when the triggers occur in each SDM cycle. For example:

SRC^DLY^MSR OUT

For this selection, an output trigger occurs after the source phase and delay phase of every SDM cycle of operation.

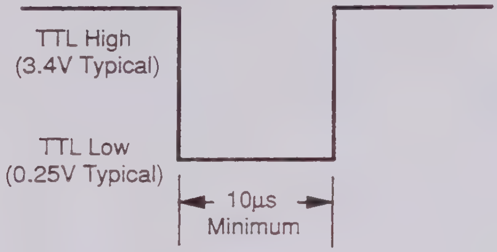


Figure 2-53. External Output Trigger Pulse Specifications

The pulse end output trigger is used exclusively for pulse sweeps. Remember that a pulse sweep is made up of a series of on times (pulse level) and off times (bias level). When the pulse end output trigger is selected, an output trigger will occur after each off time (t_{OFF}) measurement in the sweep as shown in Figure 2-54.

The pulse end output trigger is often used with the single pulse input trigger (see paragraph 2.22.1) as shown in Figure 2-57.

2.22.4 Sweep End Output Trigger

When this trigger setup is enabled, a single output trigger occurs at the end of the sweep. This output trigger is selected separately so that it can be used with a selected output (OUT) trigger. For example:

SRC^DLY MSR OUT

ENABLE SWEEP END

The first trigger setup will output a trigger after each source phase of each SDM cycle in the sweep. The second trigger setup will cause an output trigger when the Source Measure Unit returns to the bias level after the last point in the sweep.

In dc operation, sweep end trigger is ignored if it is enabled. Only output triggers selected in the OUT trigger setup will occur.

2.22.5 Enable/Disable Triggers

The triggers (input and output) of the Source Measure Unit can be disabled when the disable triggers setup is selected. With the triggers disabled, the Source Measure

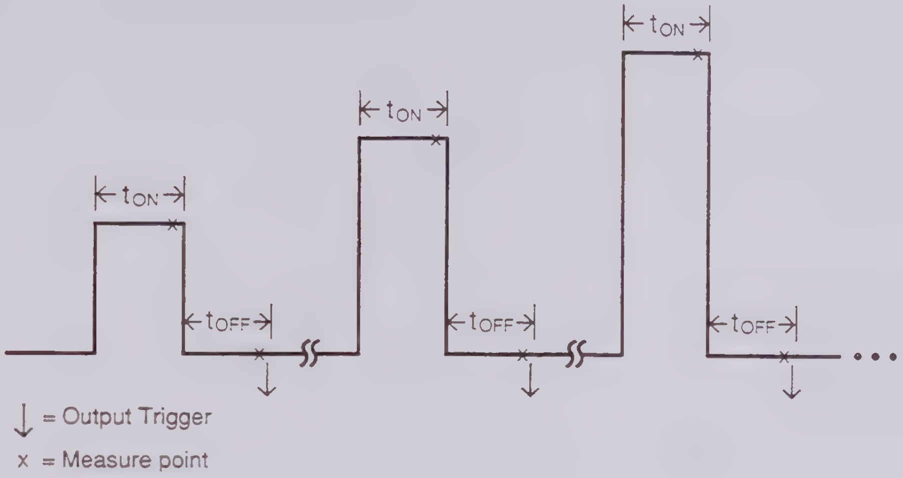


Figure 2-54. Pulse End Output Trigger

Table 2-14. Output Triggers

Trigger Selection		Description
NONE	OUT	No output triggers
SRC^DLY MSR	OUT	Output trigger pulse after every source phase.
SRC DLY^MSR	OUT	Output trigger pulse after every delay phase.
SRC^DLY^MSR	OUT	Output trigger pulse after every source phase and delay phase.
SRC DLY MSR^	OUT	Output trigger pulse after every measure phase.
SRC^DLY MSR^	OUT	Output trigger pulse after every source phase and measure phase.
SRC DLY^MSR^	OUT	Output trigger pulse after every delay phase and measure phase.
SRC^DLY^MSR^	OUT	Output trigger pulse after every source phase, delay phase, and measure phase.
PULSE END^	OUT	For pulse sweeps. Output trigger pulse after end of each off time (t_{OFF}) measurement (see Figure 2-54).

Unit cannot be triggered to start a source, delay, measure sequence (dc or sweep operation). Subsequently, output triggers cannot occur.

Being able to disable triggers provides a convenient means of putting a Source Measure Unit on "hold" without having to change the other trigger setups. For example, in a two Source Measure Unit test system, one of the units could be put on "hold" (triggers disabled) so that the second unit could be temporarily used for a different application. In another example, triggers can be disabled so that stored data can be manipulated without the possibility of a trigger starting an unwanted sweep. Remember, each sweep writes over stored data in the sweep buffer.

NOTE
A source, delay measure sequence will be terminated when triggers are disabled.

2.22.6 Trigger Configuration Procedure

General Procedure:

With trigger setup enabled, triggers are configured by selecting the appropriate setup (in, out, sweep end, origin of triggers) using the rotary knob (see Figure 2-48), displaying the desired setup selection using the SELECT buttons and then pressing ENTER. To save the configuration, press ENTER when prompted to save or cancel. This prompt (SAVE? ENTER/CANCEL) is displayed after the last setup (ENABLE or DISABLE TRIGGERS) is entered, or when Trigger SETUP is pressed.

Note: When a trigger setup selection is displayed using the SELECT buttons, the rotary knob is inoperative until the selection is entered (ENTER pressed) or cancelled (CANCEL pressed).

Detailed Procedure:

The following detailed procedure can be used to configure the triggers:

Step 1. Enable Trigger SETUP

The currently selected input trigger will be displayed. For example, if the continuous input trigger is selected, the following will be displayed:

CONTINUOUS IN

NOTE
The other trigger setups can be displayed with the rotary knob.

Step 2. Select Input Trigger

The input trigger selections are listed in Table 2-12. With the currently selected input trigger displayed (use rotary knob if needed), the SELECT buttons will display alternate input trigger selections. With the desired input trigger displayed, press ENTER.

The currently selected output trigger will then be displayed. For example, if no output trigger is selected, the following will be displayed.

NONE OUT

Step 3. Select Output Trigger

The output trigger selections are listed in Table 2-14. Alternate output trigger selections are displayed with the SELECT buttons. With the desired output trigger displayed, press ENTER.

The currently selected input trigger origin will then be displayed. For example, if the internal input trigger origin is selected, the following will be displayed:

INTERNAL ORIGIN

Step 4. Select Input Trigger Origin

The input trigger origins are listed in Table 2-13. Alternate origin selections are displayed with the SELECT buttons. With the desired origin displayed, press ENTER.

Triggers enabled/disabled will then be displayed. For example, if triggers are currently enabled, the following will be displayed:

ENABLE TRIGGERS

Step 5. Enable or Disable Triggers

The alternate trigger status is displayed with the SELECT buttons. With the desired trigger status displayed, press ENTER.

Sweep end enable or disable will then be displayed. For example, if sweep end trigger is disabled, the following will be displayed:

DISABLE SWEEP END

Step 6. Enable or Disable Sweep End Output Trigger

With sweep end output trigger enabled, an output trigger will occur at the end of a sweep. The alternate selection can be displayed with the SELECT buttons. With the desired sweep end selection displayed, press ENTER.

The following message will then be displayed:

SAVE? ENTER/CANCEL

Step 7. Save Trigger Configurations

To save the entered trigger selections, press ENTER. The unit will return to the source-measure display state. Pressing CANCEL will default the triggers to the previously programmed selections.

2.22.7 IEEE-488 Operation

The T, R and, H commands are used for trigger operations over the IEEE-488 bus.

The T command is used to configure the triggers:

T(origin),(in),(out),(sweepend)

origin — Input trigger origin:

0 = Trigger on "X"
1 = Trigger on GET
2 = Trigger on External Input
3 = Immediate trigger only

in — Input trigger effect:

0 = Continuous
1 = ^SRC DLY MSR
2 = SRC^DLY MSR
3 = ^SRC^DLY MSR
4 = SRC DLY^MSR
5 = ^SRC DLY^MSR
6 = SRC^DLY^MSR
7 = ^SRC^DLY^MSR
8 = Single Pulse

out — Output trigger generation:

0 = None
1 = SRC^DLY MSR
2 = SRC DLY^MSR
3 = SRC^DLY^MSR
4 = SRC DLY MSR^
5 = SRC^DLY MSR^
6 = SRC DLY^MSR^
7 = SRC^DLY^MSR^
8 = Pulse End

sweep end — Output trigger generation

0 = Disable
1 = Enable

NOTE
A trigger is always needed to start a sweep.

The R command is used to enable/disable triggering:

R0 = Disable triggering
R1 = Enable triggering

The H command is used for immediate triggering:

H0 = Cause immediate trigger over the bus

Sending H0 over the bus is analogous to pressing the front panel MANUAL trigger button.

HP BASIC 4.0 Programming Example:

The following program statement will configure the triggers as follows; trigger on GET (origin), single pulse input trigger (in), no output triggers (out), and enable output trigger after the end of a sweep (sweepend):

```
OUTPUT 716; "T1,8,0,1X"        Configure triggers
```

Complete information on the IEEE-488 bus and these commands can be found in Section 3 of this manual.

2.23 PERFORMING A SWEEP

With the Source Measure appropriately configured, a sweep is performed by placing the unit in OPERATE and providing the trigger(s) needed to start/control the sweep.

The following steps summarize the basic steps to perform a sweep:

Before using the Source Measure Unit, make sure it is properly connected. Detailed connection information is provided in the section labeled "Connections". It covers Source Measure Unit connections to a test fixture, and test fixture connections to a device under test (DUT). Special connection requirements are provided for test systems using a variety of switching cards. Also covered are IEEE-488 bus connections.

Step 1. Select Source and Sweep Function

To sweep voltage, select Source V Measure I, or to sweep current, select Source I Measure V.

Step 2. Configure Miscellaneous Features and Controls

Features/controls that you may wish to configure or check include; IEEE address (for bus operation), default delay, sense, integration time, and filter. These features/controls are covered in the section labeled "Operating Fundamentals".

Step 3. Create Sweep

The procedure to create a sweep is contained in paragraph 2.19.

Step 4. Append/Modify Sweep (optional)

If desired, the basic sweep created in step 5 can be customized using the append and modify features that are covered in paragraphs 2.20 and 2.21.

Step 5. Enter Compliance Value

Enter an appropriate compliance value and select an appropriate measurement range. See paragraph 2.12 for details.

Step 6. Configure Triggers

Trigger configuration is covered in paragraph 2.22.

Step 7. Place Unit in OPERATE

Step 8. Provide Input Trigger(s)

Depending on how the triggers are configured, one o more input triggers will process the sweep.

HP BASIC 4.0 Programming Example:

The basic steps summarized above to perform a sweep are repeated in the following example program. The program will create and run a 1V, 10 point, fixed level sweep that has a 2V, 10 point, fixed level sweep appended to it.

```
 10   REMOTE 716
 20   OUTPUT 716; "F0,1X"          Source V Measure I
                                   (sweep) (step 1)
 30   OUTPUT 716; "P1X"            Filter; average 2 read-
                                   ings (step 2)
 40   OUTPUT 716;                  Fixed level sweep; 1V,
      "Q0,1,0,500,10X"             autorange, 1/2 second
                                   delay, 10 points (step 3)
 50   OUTPUT 716; "B0,0,X"         Bias; 0V
 60   OUTPUT 716;                  Append fixed level
      "Q6,2,0,500,10X"             sweep; 2V (step 4)
 70   OUTPUT 716; "L.05,0X"        Compliance; 50mA,
                                   autorange (step 5)
 80   OUTPUT 716; "T1,0,0,0X"      Triggers; GET (step 6)
 90   OUTPUT 716; "N1X"            Operate (step 7)
100   TRIGGER 716                  Start sweep (step 8)
110   END
```

Complete information on the IEEE-488 bus can be found in Section 3 of this manual.

2.24 RECALLING SWEEP DATA

Every measurement that occurs in a sweep is stored in the sweep buffer and time stamped. Each time stamp indicates the elapsed time from the start of the sweep to the end of the measurement. The time stamp is useful for data logging, recording I or V versus time, and measurement of transient response times and other time-dependent effects.

Data is structured in a matrix array. Figure 2-55 shows how this array is organized. Each row of the matrix array contains six pieces of data pertaining to a data point. If the sweep took 1000 data points, a 1000 x 6 data matrix array would result.

The display of the Source Measure Unit serves as a "window" to view each piece of data in the matrix. When the Source Measure Unit is in SWEEP RECALL, the display

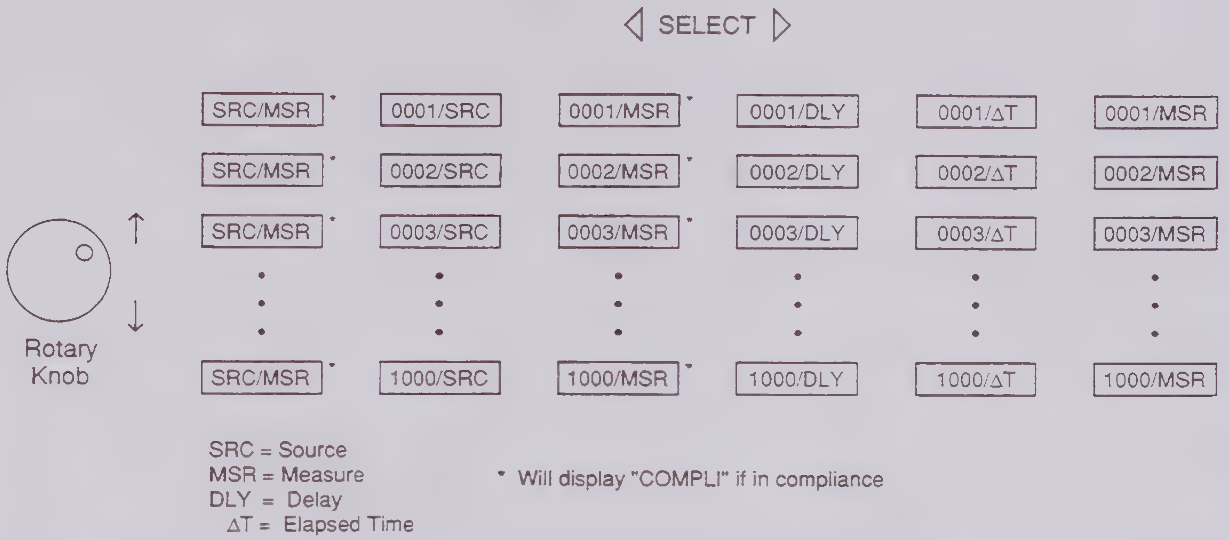

SELECT
SRC/MSR*
0001/SRC
0001/MSR*
0001/DLY
0001/ΔT
0001/MSR
SRC/MSR*
0002/SRC
0002/MSR*
0002/DLY
0002/ΔT
0002/MSR
SRC/MSR*
0003/SRC
0003/MSR*
0003/DLY
0003/ΔT
0003/MSR
Rotary Knob
SRC/MSR*
1000/SRC
1000/MSR*
1000/DLY
1000/ΔT
1000/MSR
SRC = Source
MSR = Measure
DLY = Delay
ΔT = Elapsed Time
* Will display "COMPLI" if in compliance

Figure 2-55. Sweep Buffer Data

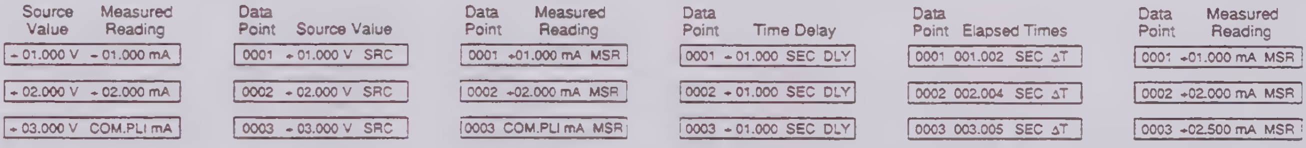

Source Value
Measured Reading
+01.000 V +01.000 mA
+02.000 V +02.000 mA
+03.000 V COM.PLI mA
Data Point
Source Value
0001 +01.000 V SRC
0002 +02.000 V SRC
0003 +03.000 V SRC
Data Point
Measured Reading
0001 +01.000 mA MSR
0002 +02.000 mA MSR
0003 COM.PLI mA MSR
Data Point
Time Delay
0001 +01.000 SEC DLY
0002 +01.000 SEC DLY
0003 +01.000 SEC DLY
Data Point
Elapsed Times
0001 001.002 SEC ΔT
0002 002.004 SEC ΔT
0003 003.005 SEC ΔT
Data Point
Measured Reading
0001 +01.000 mA MSR
0002 +02.000 mA MSR
0003 +02.500 mA MSR

Figure 2-56. Example Sweep Data

"window" is moved around in the matrix with the DATA ENTRY rotary knob and the SELECT buttons. The rotary knob moves the "window" vertically, while the SELECT buttons move the "window" horizontally in the array.

With RECALL enabled, any buffer location (measurement point) can be displayed by keying in the desired location number and pressing ENTER. Entering a value that exceeds the number of stored readings will default the display the last stored measure point.

NOTE

Figure 2-56 provides example data for a three-point linear staircase sweep. Refer to this drawing for the following descriptions of the data stored in the sweep buffer.

Source/Measure Group

The source values and subsequent measured readings are listed for every data point of the sweep. Notice that when 3V was sourced (third data point), the Source Measure Unit went into compliance and displayed the compliance message (COM.PLI).

Point/Source Group

The data point numbers and the corresponding source (SRC) values are displayed.

Point/Measure Group

The data point numbers and the corresponding measured (MSR) readings are displayed. Notice that since the Source Measure Unit went into compliance at the third data point, the compliance message is again displayed.

Point/Delay Group

Displays the data point numbers and the corresponding delay (DLY) times in seconds (SEC).

Point/Elapsed Time (ΔT) Group

Displays the elapsed time (ΔT) in seconds (SEC) from the beginning of the sweep to the end of the measurement for each data point. Notice that in addition to the programmed delay of one second, is time contributed by other factors, such as the integration time of the measurement.

Point/Measure Group

This data is similar to the other point/measure data except that the compliance message is not shown. Instead, the actual limited reading will be displayed as shown at the third data point.

NOTES:

1. When a sweep is created and/or appended/modified, the sweep buffer is immediately set up for the number of sweep points, source levels and delay times. These parameters can be checked before the sweep is run using the RECALL feature. In this situation (before the sweep is run), measurements and elapsed times are unavailable (– – –.– – –).
2. A sweep can be performed while in RECALL. This allows data to be retrieved while the sweep is in process.
3. Cycling power will not affect the last created sweep. If a sweep was run, the data (measurements and ΔT), will be retained in the buffer.
4. Performing factory initialization will clear the buffer.

IEEE-488 Bus Operation

The G command is used to send data from the sweep buffer over the bus:

G(items),(format),(lines)

items — Items in IEEE output string:

0 = No items
1 = Source value
2 = Delay value
4 = Measure value
8 = Time value

NOTE

Add up bit values of desired items (i.e. 15 sends all items)

format — Format of IEEE output string:

0 = ASCII data with prefix and suffix
1 = ASCII data with prefix, no suffix
2 = ASCII data, no prefix or suffix
3 = HP binary data
4 = IBM binary data

lines — Number of lines per output:

0 = One line of dc data per talk
1 = One line of sweep data per talk
2 = All lines of sweep data per talk

HP BASIC 4.0 Programming Example:

The following program will display one line of sweep data on the computer:

```
10  REMOTE 716
20  DIM A$ [100]
30  OUTPUT 716; “G15,0,1X”  Configure output
40  ENTER 716;A$             Talk; send one line of
                             data
50  DISP A$                  Display data
60  END
```

Complete information on the IEEE-488 bus and this command can be found in Section 3 of this manual.

2.25 MULTI UNIT OPERATION

For many test systems, two or more Source Measure Units will be required. The extensive trigger capabilities of the Source Measure Unit facilitates synchronization of Source Measure Unit operations.

The heart of multi-unit operation is the appropriate use of Source Measure Unit triggers. The available trigger selections are described in detail in paragraph 2.22. Each unit that is going to output a trigger pulse to another unit must have a BNC cable connected from its TRIGGER OUT connector to the TRIGGER IN connector of the unit receiving the trigger pulse. External trigger connections and other connection aspects are covered in detail in paragraph 2.4.

WARNING

When using the INTERLOCK feature in a multiple unit test system, make sure all the Model 236/237/238s remain powered up. Turning off one or more Model 236/237/238s in the test system may result in erratic INTERLOCK operation. That is, an operational Model 236/237/238 may not go into standby when the lid of the system test fixture is opened. This condition exposes the operator to potentially lethal voltages that could result in injury or death.

As a general rule of safety for multiple unit interlocked test systems, either keep all Model 236/237/238s powered on, or turn them all off.

There are two basic types of triggered sweeps for multi-unit operation; synchronous sweeps and subordinate sweeps.

NOTE

Even though it is possible run the following sweeps without a computer, it is usually not practical. Computer controlled test systems allow data from multiple sweeps to be stored (remember, a single Source Measure Unit can only store data for one sweep). Also, a computer can be used to analyze and manipulate the data for printing and/or plotting.

Synchronous Sweep

During a synchronous sweep, the Source Measure Units will keep triggering each other back and forth to perform specific operations until the sweep is completed.

Example:

An example of a synchronous sweep using two Source Measure Units is shown in Figure 2-57. The triggers for both units are configured the same (except for sweep end). Each input trigger will cause a single source, delay, and measure to occur. After each SDM cycle, an output trigger will occur.

An initial internal (immediate) input trigger (front panel MANUAL trigger button or H0 command over the bus) applied to unit #1 will start the sweep process. After the first SDM cycle of unit #1 is processed, an output trigger will be applied from unit #1 to unit #2 to start its sweep. After unit #2 processes an SDM cycle, it will then send an output trigger back to unit #1 to process another SDM cycle. This process of sending and receiving triggers continues until the sweeps are done. Notice that after a unit sends an output trigger, it will not process another SDM cycle until it receives another trigger from the second unit. During that time period, the source level is maintained, but delay and measure do not occur. After the dual sweep is completed, a sweep end trigger from unit #1 will return unit #2 to the bias level.

A typical application of the synchronous sweep is for semiconductor characterization. Figure 2-58 shows how the above example can be used to develop a bipolar characteristic curve (Gummel Plot). Unit #1 is used to source V_{CE} and measure I_C. Unit #2 is used to sweep V_{BE} and measure I_B.

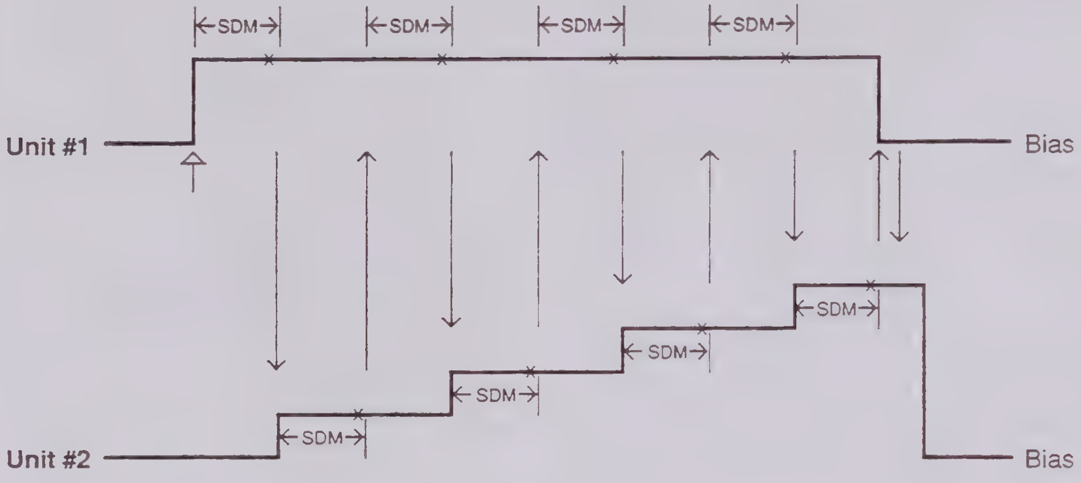
Subordinate Sweep

During a subordinate sweep, a Source Measure Unit will be triggered to perform a specific task (i.e. set a bias level), and then send an output trigger to a second Source Measure Unit to perform an entire sweep.

Example:

An example of a subordinate sweep is shown in Figure 2-59. The trigger configurations for the two units are shown in the drawing. For unit #1, each input trigger will cause a single source, delay, and measurement to occur. After each SDM cycle, an output trigger will be sent to unit #2 to perform a sweep.

An initial IEEE-488 GET command, or an internal (immediate) trigger applied to unit #1 will start the sweep process. After the first SDM cycle of unit #1 is processed, an


SDM
SDM
SDM
SDM
Unit #1
Bias
SDM
SDM
SDM
SDM
Unit #2
Bias

⇧ = Initial internal (Immediate) Trigger to start sweep

↑↓ = External Triggers

x = Measure point

Trigger Configuration (Both units)

^SRC DLY MSR IN
SRC DLY MSR^ OUT
ENABLE SWEEP END (UNIT #1)
DISABLE SWEEP END (UNIT #2)
EXTERNAL ORIGIN
ENABLE TRIGGERS

Figure 2-57. Synchronous Sweep Example

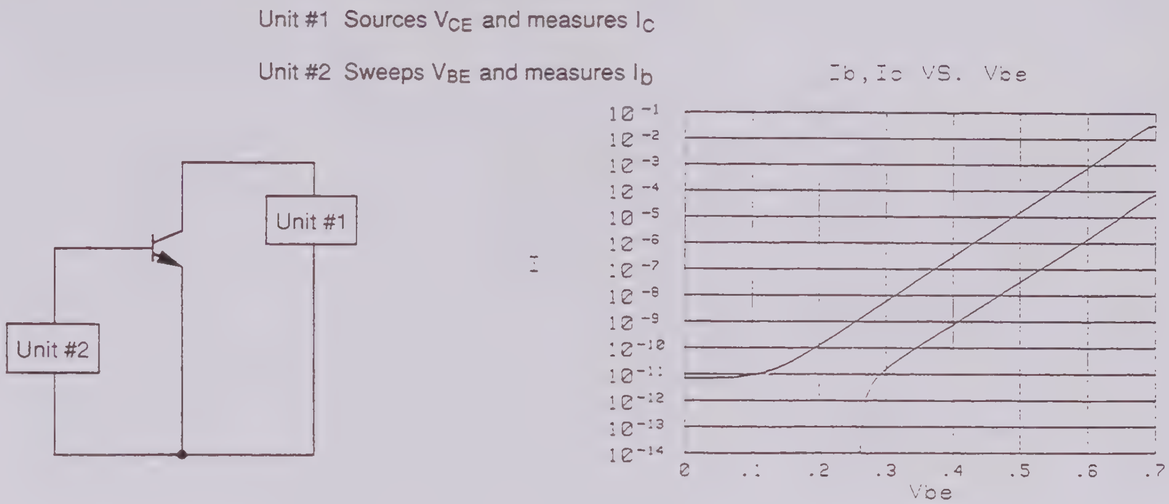


Figure 2-58. Characterization Using Gummel Plot (Synchronous Sweep)

output trigger will be applied to unit #2 to start its sweep. Since it is in the continuous input trigger mode, the entire sweep will be run. Notice that an output trigger is not sent by unit #2 after the completion of the sweep. This allows the sweep data to be retrieved and stored in computer memory. The next trigger to unit #1 is provided by a computer generated IEEE GET command. After unit #1 processes that SDM cycle, it will then apply another output trigger to unit #2 to perform another sweep. Again the computer can acquire and store the sweep data. This process continues until the last sweep for unit #2 is completed. The last IEEE GET input trigger shown in the drawing will return unit #1 to the bias level.

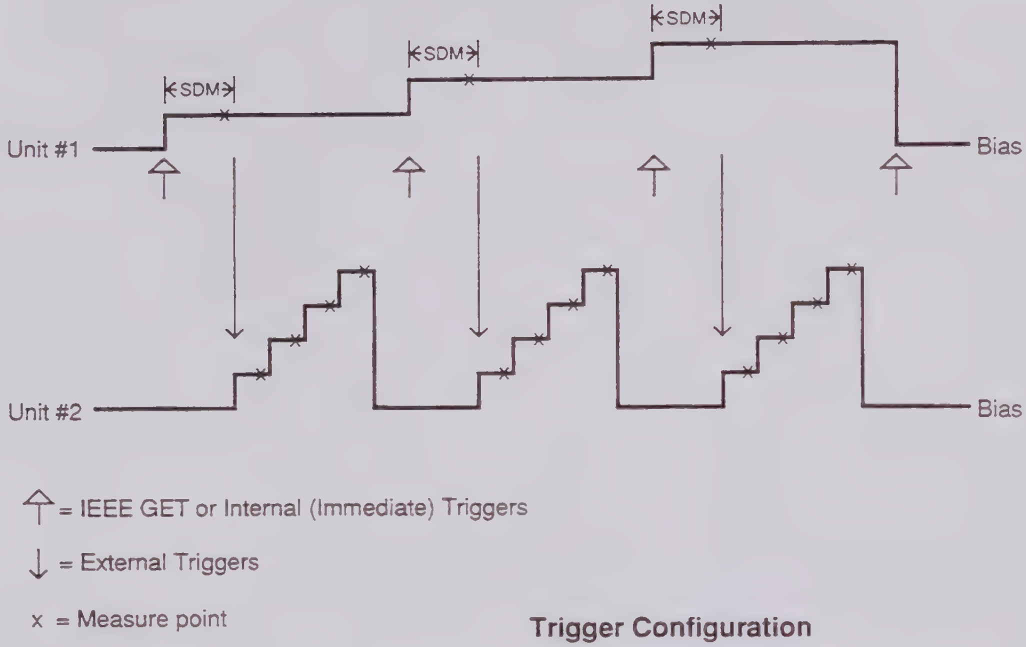
A typical application of the subordinate sweep is for semiconductor characterization. Figure 2-60 shows how the above example can be used to generate a family of curves for a bipolar transistor. Unit #1 is used to sweep V_{CE} and measure I_C. Unit #2 is used to source the three levels of base bias current for the tests.

NOTE

Comprehensive applications (over IEEE-488 bus) using synchronous and subordinate sweeps are contained in the Applications Manual.

Some guidelines on triggering to help simplify multi-unit operation:

1. Only use EXTERNAL ORIGIN triggering if you intend the Source Measure Unit to receive input triggers from other units.
2. If a unit is not intended to output trigger pulses, select NONE OUT output trigger to avoid sending inadvertent triggers to other units.


SDM
SDM
SDM
Unit #1
Bias
Unit #2
Bias
= IEEE GET or Internal (Immediate) Triggers
= External Triggers
x = Measure point

Trigger Configuration

Unit #1	Unit #2
^SRC DLY MSR IN SRC DLY MSR^ OUT DISABLE SWEEP END IEEE GET ORIGIN ENABLE TRIGGERS	CONTINUOUS IN NONE OUT DISABLE SWEEP END EXTERNAL TRIGGERS ENABLE TRIGGERS

Figure 2-59. Subordinate Sweep Example

Unit #1 Sweeps V_{CE} and measures I_C

Unit #2 Sources V_b and measures V_{BE}

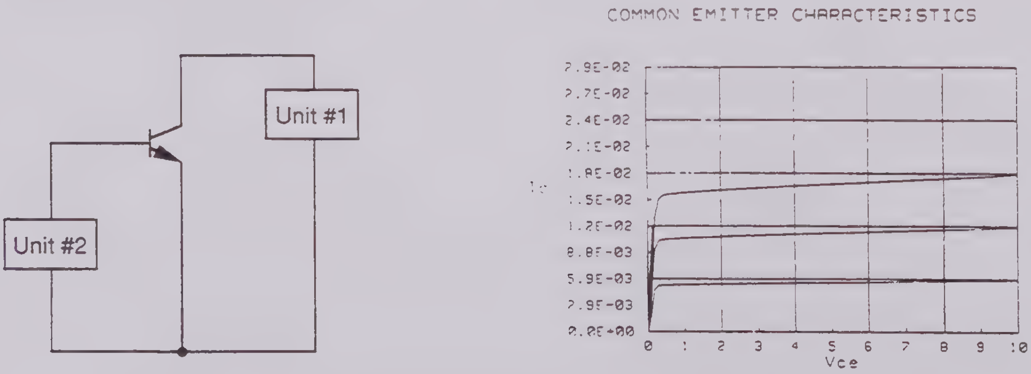


Figure 2-60. Characterization Using Family of Curves (Subordinate Sweep)

Source-Measure Considerations

2.26 CURRENT CLAMP
2.27 SINK OPERATION
2.28 MAKING STABLE MEASUREMENTS
2.29 MEASURE ONLY
2.30 GUARDING
2.31 ELECTROSTATIC INTERFERENCE
2.32 THERMAL EMFS
2.33 RADIO FREQUENCY INTERFERENCE
2.34 GROUND LOOPS

Source-Measure Considerations

2.26 CURRENT CLAMP

The Model 236/237/238 has a current clamp (I_{CLAMP}) circuit for Source V Measure I. The purpose of the I_{CLAMP} is to prevent current from exceeding the programmed current compliance limit value when an external power source is connected to the output.

An example configuration showing the I_{CLAMP} is provided by Figure 2-61. The Model 236/237/238 is programmed to source +5V with a current compliance of 10mA. The external circuit connected to the output places a 25V battery in series with the +5V programmed output. The result is a circuit that would normally provide current well in excess of the programmed compliance limit of 10mA. However, the I_{CLAMP} will enable at 10mA and limit current to that value. The I_{CLAMP} protects the Source Measure Unit and external circuitry from excessive current.

When programmed to Source I Measure V, the Model 236/237/238 does not incorporate a current clamp. Thus, current that exceeds the programmed current source value is possible when an external power source or an energy storage device is applied to the output. An example of this is shown in Figure 2-62. The external current source, formed by the 25V battery and 1kΩ resistor, in series with the output of the Model 236/237/238 will result with a current far exceeding the programmed 10mA. Also, voltage measurements (V_{METER}) by the Model 236/237/238 may be erroneous.

Caution must be exercised when using Source I Measure V to perform tests on circuits or energy storage devices (such as batteries, capacitors and inductors) that apply power to the output of the Model 236/237/238. The user may need to provide protection against excessive current and voltage surges that could damage the Model 236/237/238 or external circuitry. Figure 2-63 and Figure 2-64 summarizes some basic techniques that can be used to limit current and voltage.

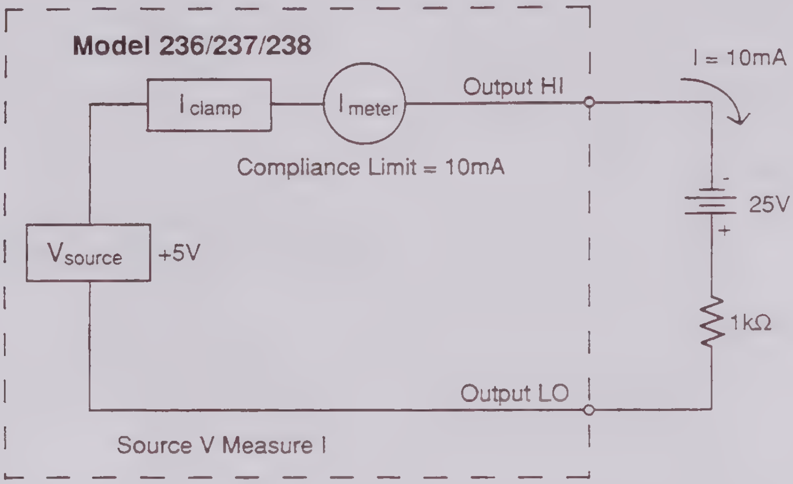

Model 236/237/238
I clamp
I meter
Output HI
I = 10mA
Compliance Limit = 10mA
-
25V
+
V source
+5V
1kΩ
Output LO
Source V Measure I

Figure 2-61. Connections to Power Source (Source V)

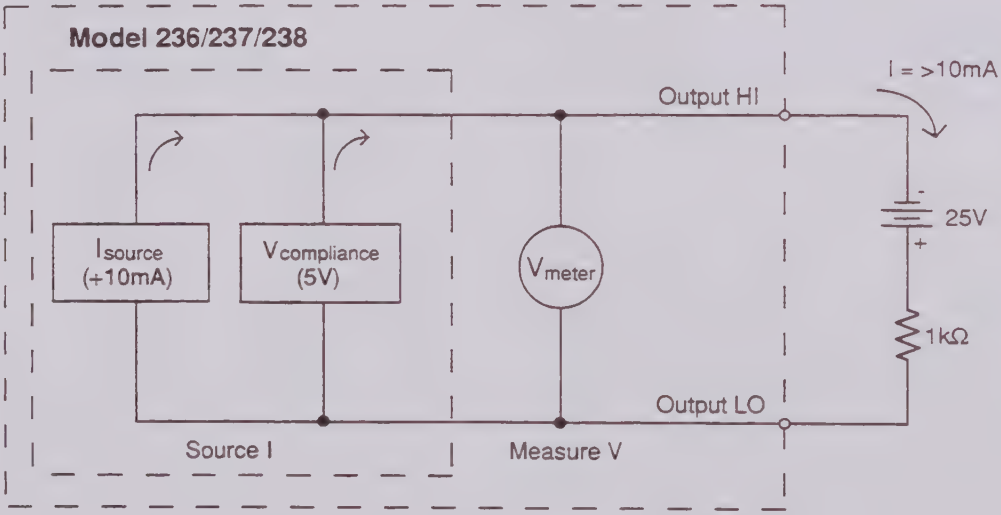

Model 236/237/238
Output HI
I = >10mA
-
25V
+
I source
(+10mA)
V compliance
(5V)
V meter
1kΩ
Output LO
Source I
Measure V

Figure 2-62. Connections to Power Source (Source I)

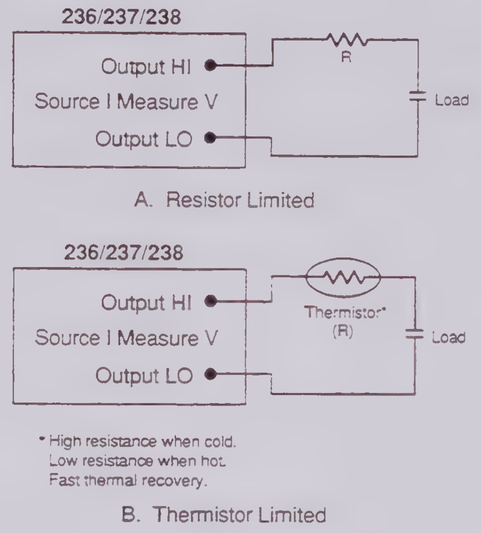

236/237/238
Output HI
Source I Measure V
Output LO
R
Load
A. Resistor Limited
236/237/238
Output HI
Source I Measure V
Output LO
Thermistor*
(R)
Load
* High resistance when cold.
Low resistance when hot.
Fast thermal recovery.
B. Thermistor Limited

Figure 2-63. Limiting Capacitive Reaction Current

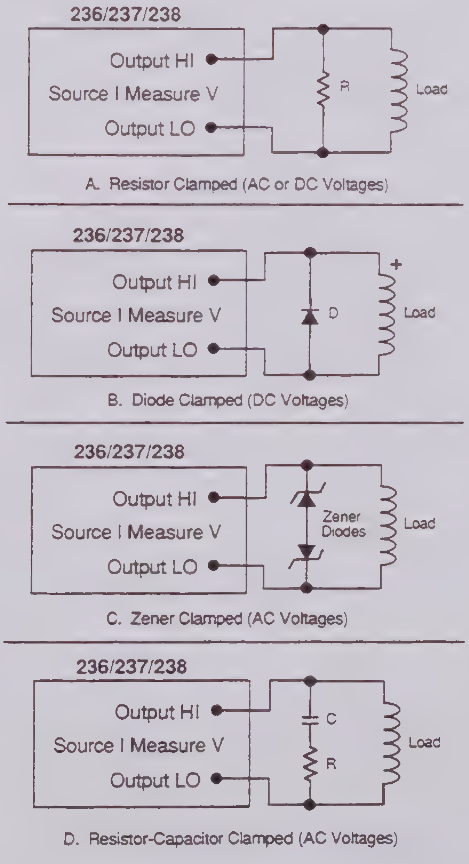

236/237/238
Output HI
Source I Measure V
Output LO
R
Load
A. Resistor Clamped (AC or DC Voltages)
236/237/238
Output HI
Source I Measure V
Output LO
D
+
Load
B. Diode Clamped (DC Voltages)
236/237/238
Output HI
Source I Measure V
Output LO
Zener Diodes
Load
C. Zener Clamped (AC Voltages)
236/237/238
Output HI
Source I Measure V
Output LO
C
R
Load
D. Resistor-Capacitor Clamped (AC Voltages)

Figure 2-64. Limiting Inductive Reaction Voltage

2.27 SINK OPERATION

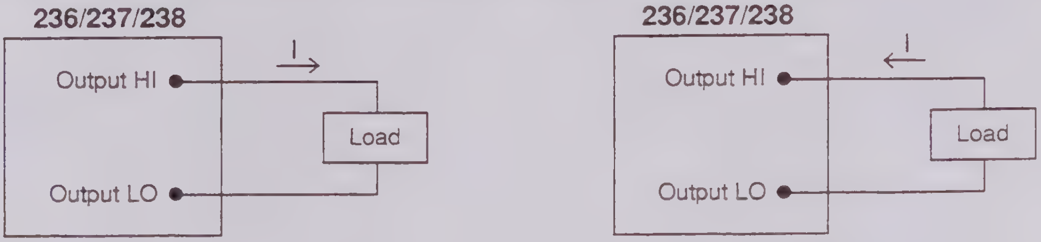
The Model 236/237/238 functions as a source when it is delivering power to a load. During normal source operation, current will flow out of OUTPUT HI when programmed for a positive output (see Figure 2-65A). The positive output would result in a positive measurement placing operation in quadrant I (see Figure 2-66). When programmed for a negative output, current will flow into OUTPUT HI (see Figure 2-65B). The negative output will result in a negative measurement placing operation in quadrant III.

With an external source or an energy storage device (such as a battery, capacitor or inductor) connected to the output, the Model 236/237/238 could operate as a sink. As a sink, it will dissipate power rather than source power. For example, a test system to check a battery may require that it be charged and then discharged. The Model 236/237/238 operates as a source while charging the battery. When programmed to allow the battery to discharge, the Model 236/237/238 will operate as a sink.

Constant I Load

The Source Measure Unit can be configured to function as a constant current load. The example test system in Figure 2-67 shows the most accurate method to use the instrument as a constant current load. Assume that the test requires the 12V battery to be discharged at 1mA. To accomplish this, the Model 236/237/238 is configured to Source I Measure V. The I_{SOURCE} is set to output −1mA and $V_{COMPLIANCE}$ is set to 20V. $V_{COMPLIANCE}$ must be greater than 12V to keep the Source Measure Unit from going into compliance. Configured in this manner, the Model 236/237/238 will sink a constant 1mA from the discharging battery. The Source Measure Unit will be operating as a sink in Quadrant II (−I, +V). If the polarity of the battery and I_{SOURCE} were reversed, the Model 236/237/238 would operate as a sink in Quadrant IV (+I, −V).

Another way to use the Model 236/237/238 as a constant current load is shown in Figure 2-68. The Source Measure Unit is configured to Source V Measure I. With V_{SOURCE} set to a value less than 12V, the battery will discharge current into the Source Measure Unit. The test requires that the battery discharge at 1mA. With V_{SOURCE} set to 0V, the battery could discharge much more current than 1mA. However, with current compliance limit set to 1mA, the Model 236/237/238 will go into compliance and the battery will discharge at a constant 1mA. This method of controlling current with the I_{CLAMP} is not as accurate as the previous method that controls current with the I_{SOURCE}.



A. Programmed for Positive Output

B. Programmed for Negative Output

Figure 2-65. Source Operation

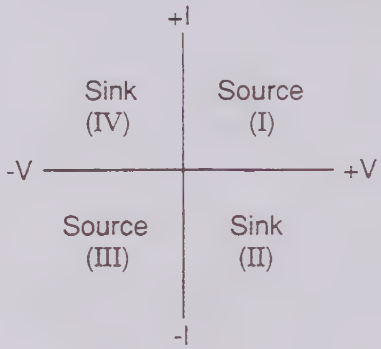


Figure 2-66. Operating Quadrants

Constant V Load

The Model 236/237/238 can be configured to function a constant voltage load as shown in Figure 2-69. In this example, a constant 1mA current source is connected to the output of the Source Measure Unit. The Model 236/237/238 is programmed to Source V Measure I. V_{SOURCE} is set to the desired voltage. In this case it is set to +5V. Current compliance is set to a value that exceeds the source current level to keep the Source Measure Unit from going into compliance, yet still provides circuit protection. In this example, current compliance is set to 2mA. As configured, the Model 236/237/238 will sink 1mA at a constant voltage of +5V.

CAUTION

With an external source or energy storage device connected to the output, current is not limited when in Source I Measure V. Refer to paragraph 2.26 for precautions against excessive current that could damage the Model 236/237/238 or external circuitry.

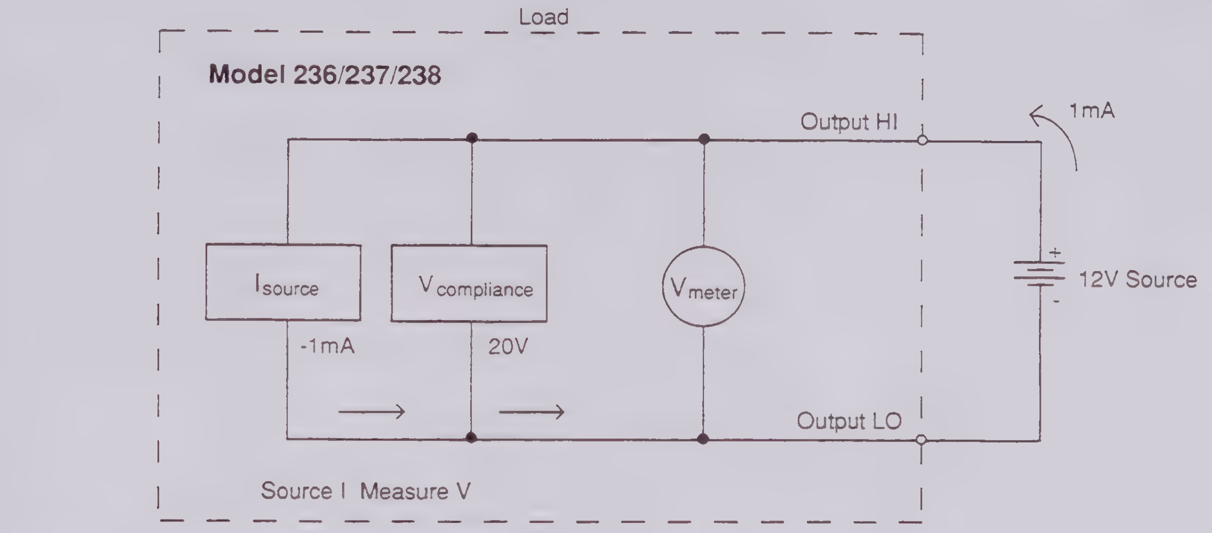

Load
Model 236/237/238
Output HI
1mA
Isource
-1mA
Vcompliance
20V
Vmeter
+
12V Source
-
Output LO
Source I Measure V

Figure 2-67. Constant I Load (Source I Measure V)

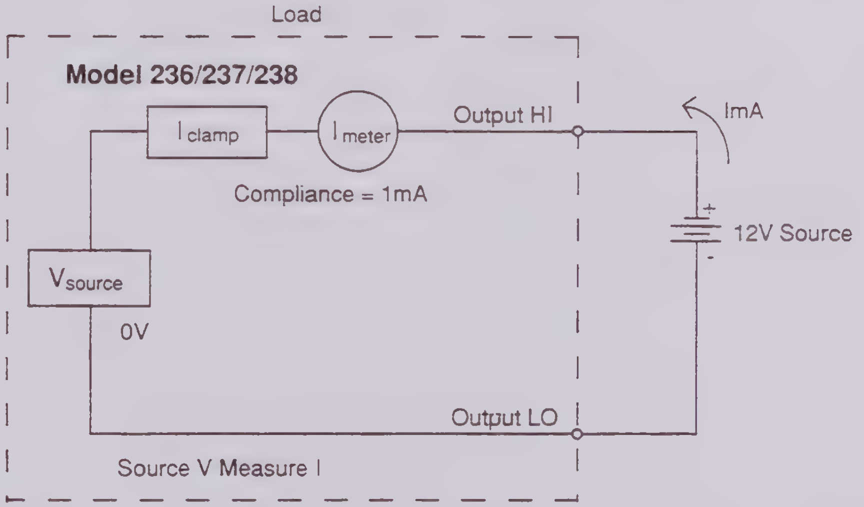

Load
Model 236/237/238
Iclamp
Imeter
Output HI
ImA
Compliance = 1mA
+
12V Source
-
Vsource
0V
Output LO
Source V Measure I

Figure 2-68. Constant I Load (Source V Measure I)

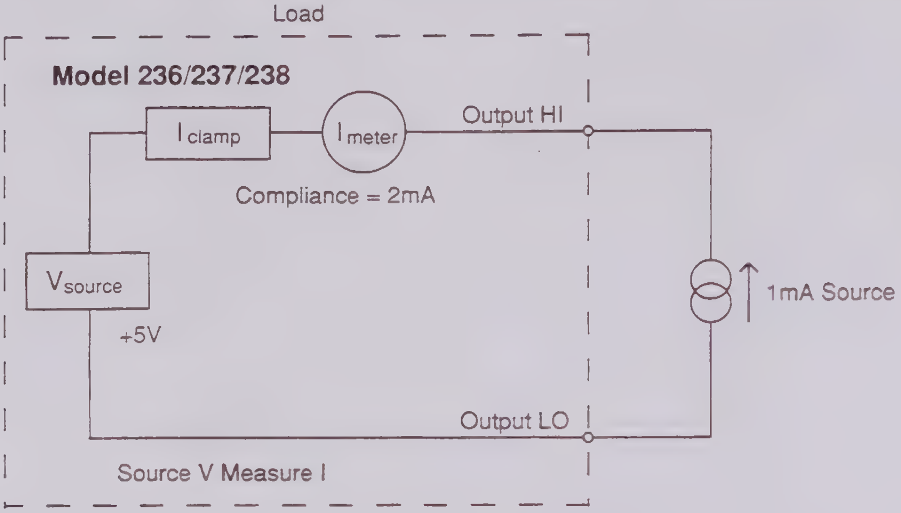

Load
Model 236/237/238
I clamp
I meter
Output HI
Compliance = 2mA
V source
+5V
1mA Source
Output LO
Source V Measure I

Figure 2-69. Constant V Load

2.28 MAKING STABLE MEASUREMENTS

Stability Considerations (Single Source Measure Unit)

The output impedance models of the Source Measure Unit are shown in Figure 2-70 and Figure 2-71. When sourcing current (Figure 2-70), large inductive loads (L_{LOAD}) may cause the Source Measure Unit to oscillate due to the resonant tank circuit that is formed (L_{LOAD} in parallel with C_{OUT}). The Source Measure Unit uses an R-C damper network to help degrade the Q of this resonant circuit. The lower the Q of a tank circuit, the less likely it is to oscillate.

Oscillations are most susceptible on the 110V and 1100V measurement ranges where the bandwidth is large (>200kHz). On these ranges, the Source Measure Unit can handle up to 100µH loads. The Source Measure Unit is much less susceptible on the lower measurement ranges (1.1V and 11V for the 236/237, 1.5V and 15V for the 238). On these ranges, the Source Measure Unit may handle five times more inductance. When larger inductive loads are encountered, a series resistor (approximately 100Ω) can be used to degrade the Q of the circuit.

$$\text{Where; } Q = W_O RC \quad W_O = \frac{1}{\sqrt{LC}}$$

When sourcing voltage, the output looks inductive. As a result, capacitive loads will degrade phase margin. The Source Measure Unit is designed for a 45° phase margin into 3000pF and as a result will handle much higher capacitances without oscillating. In addition, the effective series resistance (ESR) of the capacitor (especially large value electrolytic types) helps limit the Q of the resonant circuit. Adding an external series resistor (100Ω) will help decouple large capacitive loads.

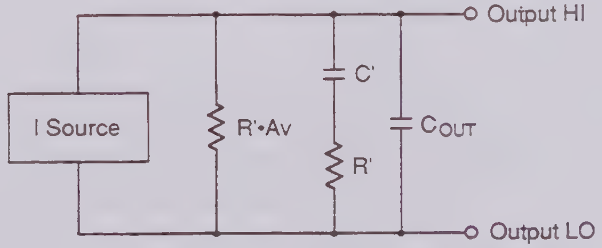
Stability in Multi-Unit Test Systems

Using two or more Source Measure Units to test an active device (such as a bipolar transistor) can aggravate system stability. An example of a valid characterization curve for a transistor is shown in Figure 2-72A. Figure 2-72B shows what can happen to the data curve if the system oscillates.

In general, oscillations can be classified in two categories; high frequency oscillations (200kHz through 200MHz) and low frequency oscillations (below 200kHz).

High Frequency Oscillations

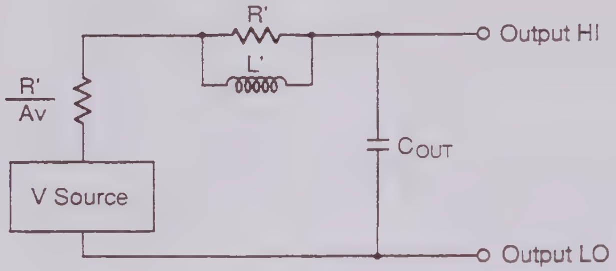
High frequency oscillations are a result of parasitic inductances and capacitances that exist around the device under test (DUT). The values of these inductances and capacitances are not affected by the Source Measure Units. Figure 2-73 shows a typical connection scheme using two Source Measure Units to test a bipolar transistor. It includes the inductances and capacitances that exist



R' = Range resistor
A_V = Loop gain (10^6)
$C' = \frac{1}{2\pi BWR'}$ BW = 40 kHz for 1.1V, 1.5V, 11V, and 15V ranges
= 200 kHz for 110V and 1100V ranges

C_{OUT} = Fixed capacitor (depends on selected current range)

Figure 2-70. I-Source Output Impedance Model

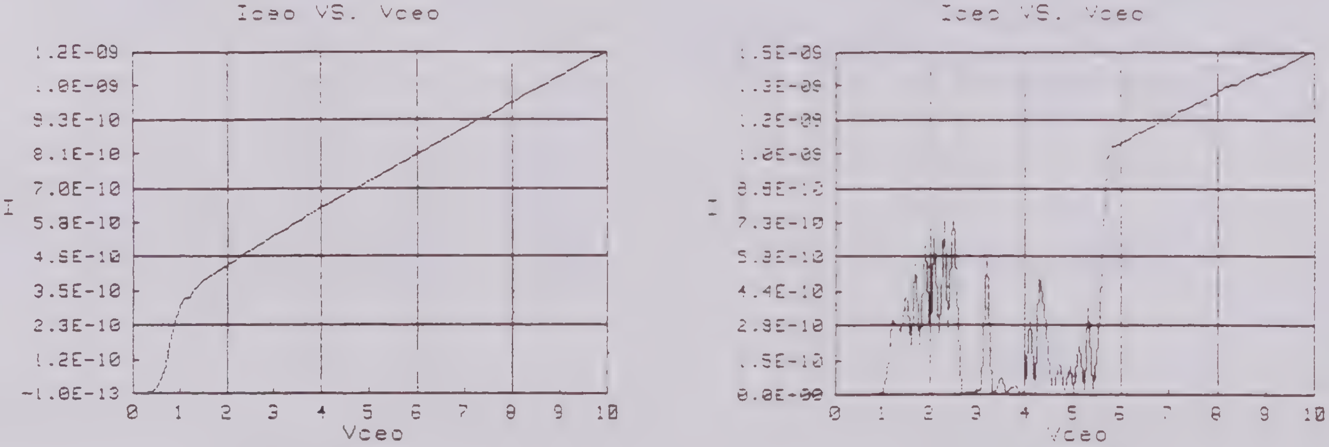


R' = Current range resistor
A_V = Loop gain (10^6)

$L' = \frac{R'}{2\pi BW'}$ BW = 40 kHz for 1.1V, 1.5V, 11V, 15V and 110V ranges
= 4 kHz for 1100V range

C_{OUT} = Fixed capacitor (depends on selected current range)

Figure 2-71. V-Source Output Impedance Model



A. Without Oscillations
(Valid data)

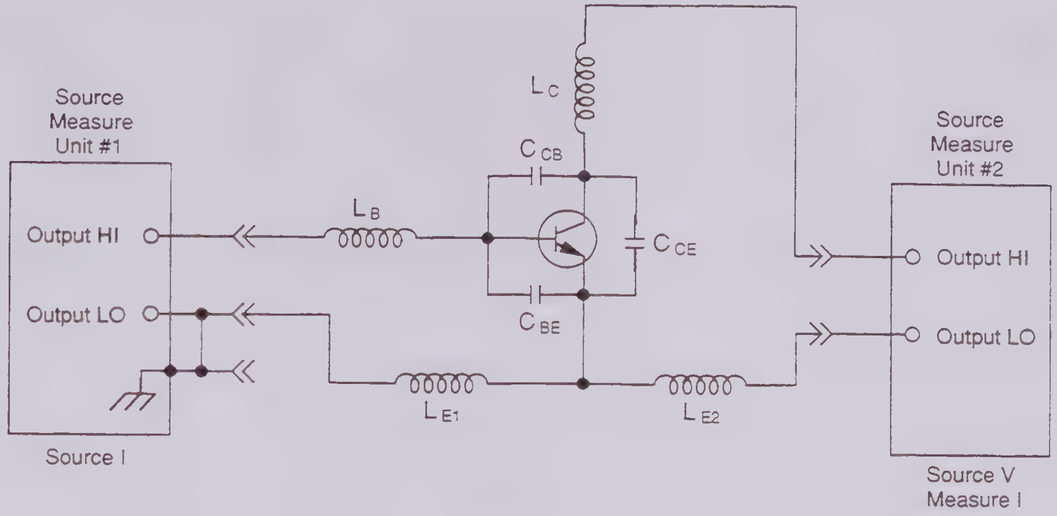
B. With Oscillations
(Invalid Data)

Figure 2-72. Oscillation Effects on Test Data

around the transistor. Source Measure Unit #1 is used to apply base current to the transistor, and Source Measure Unit #2 provides collector-to-emitter voltage and measures collector current. At high frequencies, the output of both Source Measure Units look capacitive.

In Figure 2-73, C_{CB} and L_B form a feedback network to the base of the transistor. This network has a resonant frequency (f_O) that is calculated as follows:

$$F_O = \frac{1}{2\pi\sqrt{L_B C_{CB}}}$$



C_{CB} = collector-to-base capacitance
C_{BE} = base-to-emitter capacitance
C_{CE} = collector-to-emitter capactance
L_C = collector inductance
L_B = base inductance
L_E = emitter inductance

Figure 2-73. DUT Inductances and Capacitances

The test system will oscillate at that frequency (f_O) if the Q of the circuit is high enough. In a similar manner, an oscillator can also be formed by the emitter feedback network (L_E and C_{BE}).

Examples:

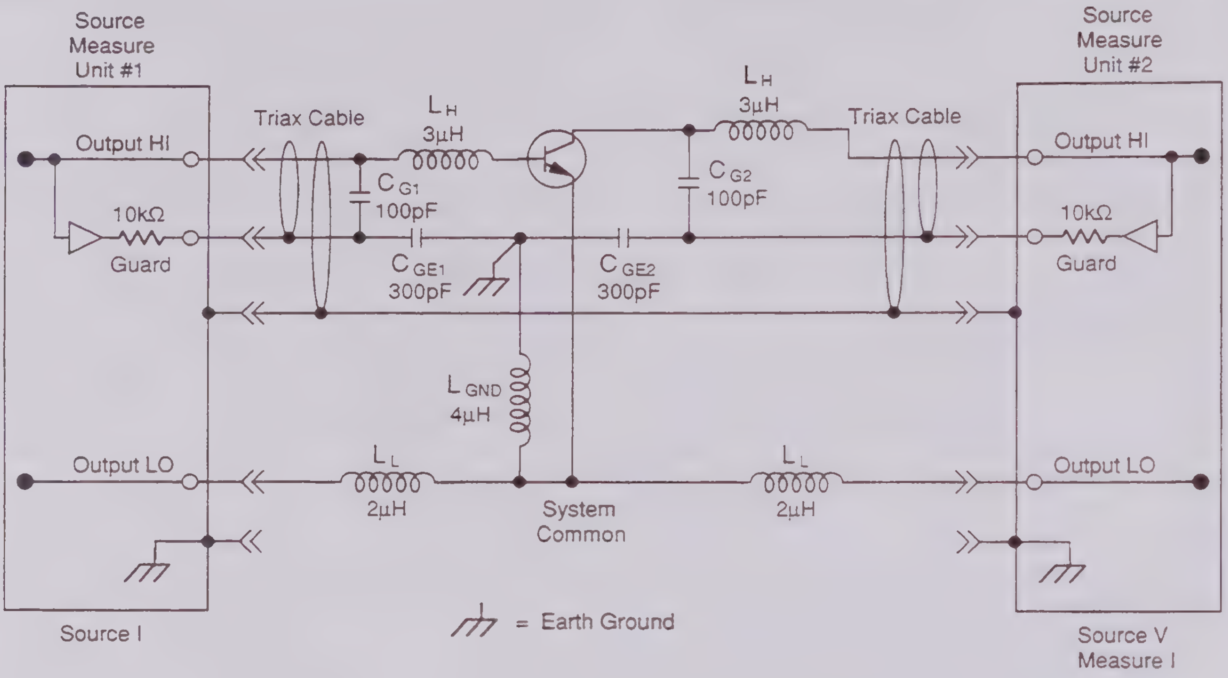
if; $L_B = 3\mu H$ $C_{CB} = 1.5pF$ then; $f_O = 75MHz$
if; $L_E = 2\mu H$ $C_{BE} = 50pF$ then; $f_O = 16MHz$

Note that the active device need not be a bipolar transistor. A MOSFET or GaAs FET will present similar problems.

To prevent oscillations, resistors can be connected in series with the DUT, or ferrite beads can be used on the DUT leads. Each ferrite bead or resistor will help damp out a high circuit Q (Q = WRC). Typically, ferrite beads add 100Ω at high frequencies, therefore several ferrite beads in series may be needed. There are different types of ferrite beads that are designed for specific frequency ranges. For example, Fair-Rite p/n 2673000301 is used for the 10Mz to 40MHz frequency range and Fair-Rite p/n 264300301 covers the 40Hz to 200MHz range. These ferrite beads are small enough to clip over the leads allowing them to be located close to the DUT. It is good practice to use a ferrite bead combination that will cover a wide bandwidth. The Keithley Model 8006 test fixture uses ferrite beads on all test sockets to eliminate or minimize oscillations. When using a semiconductor prober station or a custom built test fixture, ferrite beads or additional resistors may be necessary to prevent high frequency oscillation. Ferrite beads should be installed on the leads as close to the DUT as possible.

Cable capacitances and inductances around the DUT (see Figure 2-74) may also cause high frequency oscillation. The values shown in the illustration are typical for a triax cable one meter in length.

C_G is the capacitance that exists between the center conductor (Output Hi) and the inner shield (Guard) of each triax cable. C_{GE} is the capacitance between the inner shield and the outer shield (chassis ground). L_{GND} is a


Source Measure Unit #1
Output HI
10kΩ
Guard
Output LO
Source I
Triax Cable
L_H 3μH
C_{G1} 100pF
C_{GE1} 300pF
L_{GND} 4μH
L_L 2μH
System Common
= Earth Ground
L_H 3μH
C_{G2} 100pF
C_{GE2} 300pF
Triax Cable
L_L 2μH
Source Measure Unit #2
Output HI
10kΩ
Guard
Output LO
Source V Measure I

C_G = capacitance between the center conductor and inner shield of each triax cable.
C_{GE} = capacitance between the inner shield and outer shield of each triax cable.
L_H = inductance of the center conductor of each triax cable.
L_L = inductance of each output low conductor.
L_{GND} = inductance of the cable used to connect system common to earth ground.

Figure 2-74. Cable Capacitances and Inductance

separate single conductor cable used to connect system common to earth ground. This is a recommended practice, especially for low current measurements.

C_{GE1}, C_{GE2} and L_{GND} form a feedback network around the DUT. Because of the internal 10kΩ guard resistor, GUARD cannot attenuate the signal from the network (at high frequencies). As a result, the signal is connected to the DUT via C_{G1} and C_{G2} cable capacitance. The resonant point (f_O) that exists is calculated as follows:

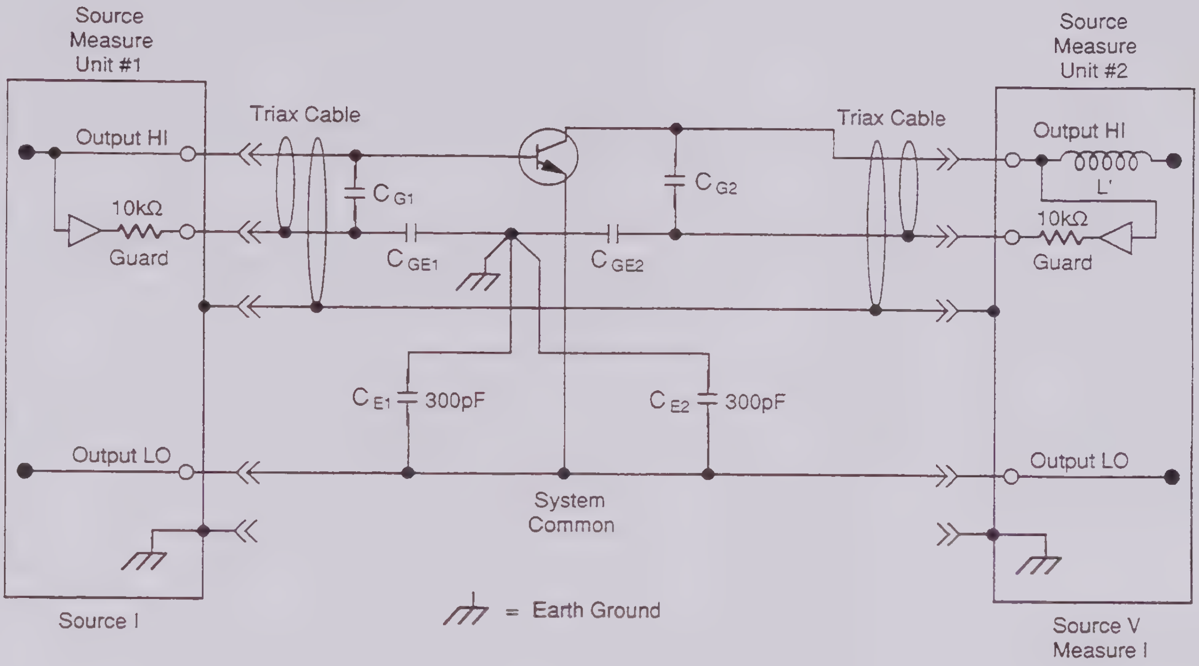
$$f_O \sim \frac{1}{2\pi\sqrt{C_{GE}\,L_{GND}}}$$

A simple way to eliminate oscillations due to cable capacitance and inductance is to install the ground link on the rear panel of Source Measure Unit #1. This ground link connects OUTPUT LO to chassis (earth) ground. The inductance of the ground link is 20nH (as opposed to 4μH for the separate ground wire) pushing f_O up to a frequency region where the ferrite beads can damp out Q, or possibly to a frequency above f_T of the DUT.

Low Frequency Oscillations

Low frequency (dc through 200kHz) oscillation problems may also occur in multiple Source Measure Unit test systems. Figure 2-75 shows a floating test system (system earth ground wire removed. With the ground wire removed, capacitance (C_{E1} and C_{E2}) exists between OUTPUT LO and earth ground.

Capacitors C_{G1}, C_{GE1}, C_{G2}, C_{GE2}, C_{E1} and C_{E2} form a feedback path around the DUT. At lower frequencies, the impedance of Source Measure Unit #2 looks inductive as indicated by L′. Thus, the inductive load (L′) is applied to



C_G = capacitance between the center conductor and inner shield of each triax cable.
C_{GE} = capacitance between the inner shield and outer shield of each triax cable.
C_E = capacitance between output low and earth ground.

Figure 2-75. Cable Capacitances in a Floating Test System

the capacitive divider (feedback path) through C_{GE2} (via C_{G2} and the guard buffer). A portion of the feedback current will make it through C_{G1} if the guard impedance of Source Measure Unit #1 is high enough. Thus, the possibility for oscillations exists, especially with Source Measure Unit #1 on a low current range. The lower the current range, the higher the output impedance of the Source Measure Unit. The base current for the DUT is more easily "pushed around" by the feedback through C_{G1} on the lower current ranges.

These low frequency oscillations may be eliminated by installing the ground link (OUTPUT LO to chassis ground) on the rear panel of Source Measure Unit #1. The ground link effectively shunts out all feedback signals to system low. Another possible solution is to connect an external capacitor from the base to the collector of the transistor (DUT). This will help "swamp out" the undesired feedback signals through C_{G1}. The value of the external capacitor should be 10 to 20 times the value of the base-to-collector capacitance of the device (C_{CB}). The capacitor must be constructed of high quality polystyrene or polypropylene to ensure that system DC performance is not degraded.

Other types of low frequency oscillation may arise due to dynamic parameter variations of the DUT as the operating point changes. These are most likely to occur when the device exhibits drastic impedance changes, such as entering and exiting saturation, or negative impedance behavior during breakdown. These types of oscillations are difficult to predict and model, as linear small signal analysis of this system may not apply. The following guidelines will aid in eliminating these types of oscillations as well as the previously discussed types.

Guidelines To Prevent System Oscillations

1. To prevent high frequency oscillations, use ferrite beads or 100Ω resistors in series with the DUT leads. Recommended ferrite beads:

10MHz - 40MHz; Fair-Rite 2673000301
40MHz – 200MHz; Fair–Rite 2643000301

2. Add 100pF polystyrene capacitor (Keithley C-138-100pF) from base (gate) to collector (drain). This reduces the loop gain at high frequencies, thus increasing gain margin. This capacitor can also "swamp out" the effects of unwanted feedback networks arising from floating or long ground returns.
3. Add 330pF polystyrene capacitor (Keithley C-138-330pF) from base (gate) to emitter (source). This provides capacitive divider effect on feedback from collector (drain) to base (gate), reducing loop gain at higher frequencies. This technique may be very effective when the Source Measure Unit that is supplying power to the base (gate) of the DUT is on a low current range. The capacitor "stiffens" the base-emitter impedance at high frequencies.
4. Use 100pF to 1000pF polystyrene capacitors to bypass collector (drain) to emitter (source). This helps decouple inductances of cables or output impedances of other Source Measure Units.
5. Install the ground link connecting OUTPUT LO to chassis ground on the Source Measure Unit that is providing current to the base (gate) of the DUT. Only one Source Measure Unit should have the ground link installed in order to avoid ground loops. The ground link prevents high and low frequency oscillations.

2.29 MEASURE ONLY

The Source Measure Unit can be used as a stand-alone voltmeter or current meter. Using the Source Measure Unit to make routine DMM type measurements is covered in Getting Started (paragraph 1.2). In general, measure only requires that the Source Measure Unit be set to source 0.0000V to measure current, or 0.0000nA to measure voltage. Program compliance for the desired measurement range. OUTPUT HI and OUTPUT LO are then used to make the measurement.

Special input characteristics of the Source Measure Unit allow it to be used to make electrometer type measurements. These characteristics include:

>$10^{14}\Omega$ Input Impedance — The high input impedance prevents circuit loading when making voltage measurements of high impedance devices.

Low Current Measurement Ranges — On the 1nA range, measurement resolution (at 5-digits) is 10fA.

<1mV Voltage Burden — The low voltage burden prevents circuit loading when measuring currents from sources of a few volts or less.

GUARD — The driven guard is available to eliminate the effects of leakage current in test cables that can adversely affect low level measurements.

Figure 2-76 and Figure 2-77 show how to configure the Source Measure Unit for electrometer type measurements.

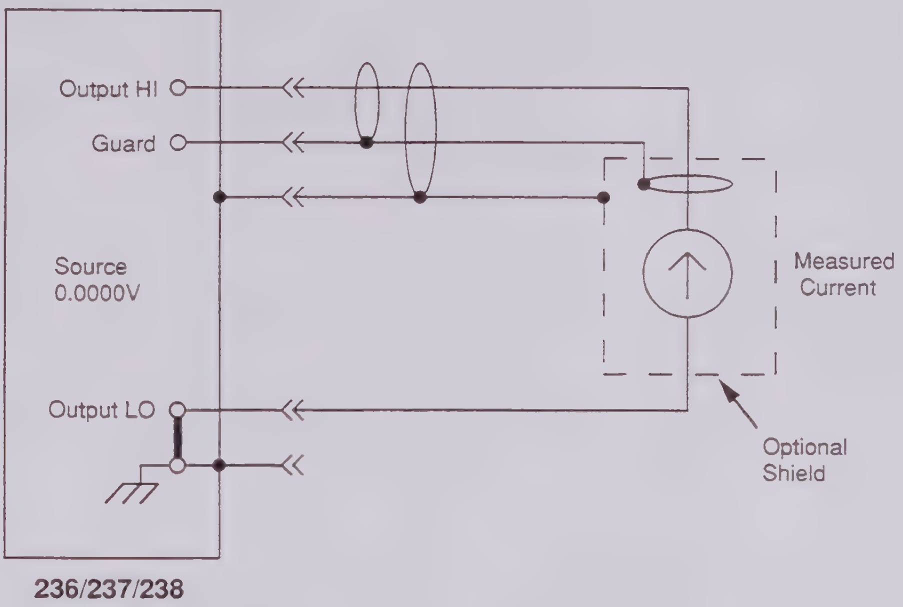

Output HI
Guard
Source
0.0000V
Output LO
Measured
Current
Optional
Shield
236/237/238

Figure 2-76. Electrometer Current Measurements Only

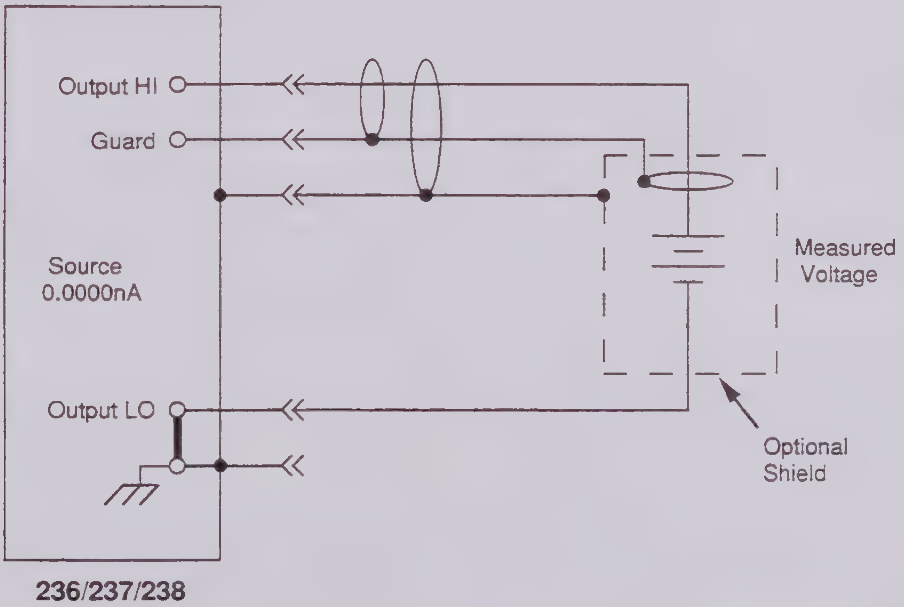

Output HI
Guard
Source
0.0000nA
Output LO
Measured
Voltage
Optional
Shield
236/237/238

Figure 2-77. Electrometer Voltage Measurements Only

2.30 GUARDING

When sourcing or measuring low current, leakage current can be significant enough to adversely affect performance. Guarding uses a conductor at essentially the same potential seen at OUTPUT HI. The driven guard, which is used to surround OUTPUT HI and SENSE HI, drastically reduces leakage current and the effects of cable capacitance.

NOTE

> Figure 2-78 and Figure 2-79 are used to help explain the principles of guarding. Both illustrations show LO being connected to chassis ground. On the Source Measure Unit, OUTPUT LO can be connected to chassis ground by installing the ground link on the rear panel. Even with the ground link removed, the resistance between OUTPUT LO and chassis ground (10GΩ) is relatively low when compared to the insulation resistance of the cable (100GΩ). Thus, for the following discussion on low level leakage currents, the outer shield of the cables (chassis ground) can be considered to be OUTPUT LO.

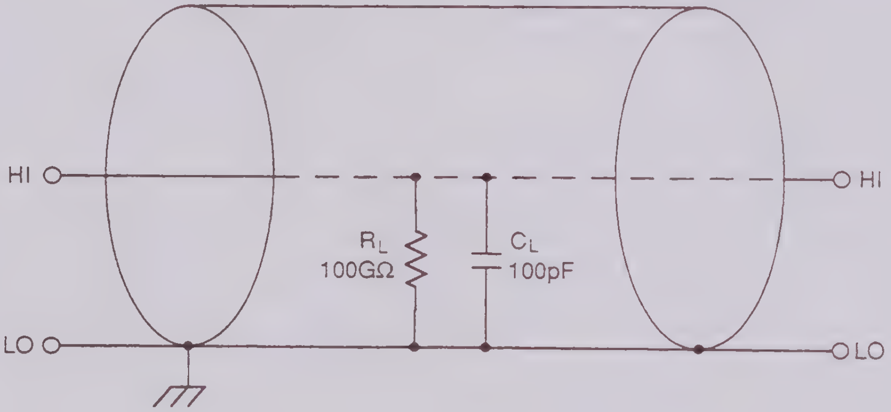


Figure 2-78. Unguarded Coaxial Cable

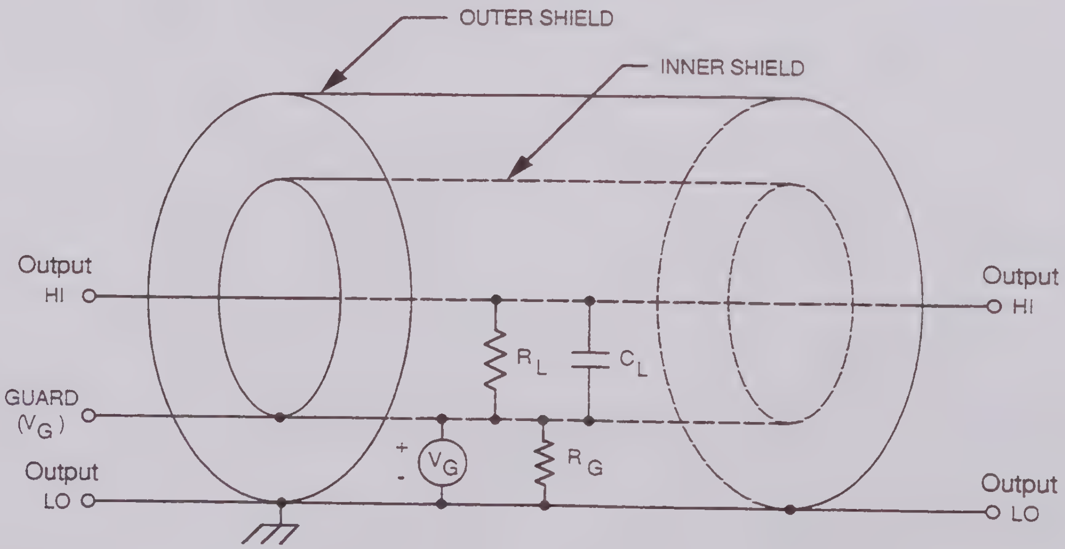


Figure 2-79. Guarded Triax Cable

Leakage Current Effects

Typically, insulation resistance between conductors in a coaxial or triaxial cable is 100GΩ (see Figure 2-78). In this unguarded configuration, leakage current will flow through the insulator (represented by R_L and C_L) separating HI from LO.

Leakage current is a problem in an unguarded circuit when sourcing or measuring current for a high impedance load. For example, assume the Source Measure Unit is set to output 1nA to a 1GΩ load. The 1GΩ load will be in parallel with the leakage resistance RL (100GΩ) resulting with ~990pA being delivered to the load. The other 10pA will leak through the insulator. The end result is a 1% sourcing error.

Figure 2-79 shows the general guarding technique using a triax cable. GUARD (V_G) is connected to the inner shield of the cable and surrounds OUTPUT HI. Since the guard voltage is at virtually the same potential as OUTPUT HI, leakage current through the insulator will be almost zero. In reality, GUARD and OUTPUT HI differ by a small offset voltage (±2mV). The actual maximum leakage current (I_L) would be:

$$I_L = \frac{2\text{mV}}{100\text{G}\Omega} = 20\text{fA}$$

Leakage current will flow from the inner shield to the outer shield (through R_G), but it does not matter since the current is supplied by buffered guard source (V_G) and not OUTPUT HI.

Cable Capacitance Effects

Without guarding, the effects of cable capacitance (C_L in Figure 2-78) could adversely affect the settling time when sourcing current. The rise time of the source depends on the total shunt capacitance seen at its output. For a high impedance load, even a small amount of cable capacitance can result in long rise times. For example, cable capacitance of 100pF and a load resistance of 1GΩ will result in an RC time constant of approximately 100msec. Guarding (see Figure 2-79) would drastically reduce cable capacitance resulting in much faster rise times. With OUTPUT HI and GUARD at virtually the same potential, C_L cannot charge. Thus, rise time is not affected by cable capacitance.

When sourcing voltage, the rise time due to cable capacitance is usually insignificant. Since the voltage source is low impedance (<1Ω), the RC time constant of 10^{-10} seconds (1Ω × 100pF) would be negligible.

2.31 ELECTROSTATIC INTERFERENCE

Electrostatic interference occurs when an electrically charged object is brought near an uncharged object, thus inducing a charge on the previously uncharged object. Usually, the effects of such electrostatic action are not noticeable because low impedance levels allow the induced charge to dissipate quickly. However, high impedance levels of many Source Measure Unit measurements do not allow these charges to decay rapidly, and erroneous or unstable readings may be caused in the following ways:

1. Dc electrostatic fields can cause undetected errors or noise in the reading.
2. Ac electrostatic fields can cause errors by driving the amplifier into saturation, or through rectification that produces dc errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment cause fluctuations in the reading. Pick up from ac fields can also be detected by observing the output on an oscilloscope. Line frequency signals on the output are an indication that electrostatic interference is present.

Means of minimizing electrostatic interference include:

1. Shielding. Possibilities include; a shielded room, a shielded booth, shielding the sensitive circuit (test fixture), and using shielded cable. The shield should always be connected to a solid connector that is connected to signal low. Note, however, that shielding can increase capacitance, possibly slowing down response time.
2. Reduction of electrostatic fields. Moving power lines or other sources away from the experiment reduces the amount of electrostatic interference seen

2.32 THERMAL EMFS

Thermal EMFs are small electric potentials generated by differences in temperature at the junction of two dissimilar metals. Low thermal connections should be used whenever thermal EMFs are known to be a problem.

Crimped copper to copper connections can be used to minimize these effects.

2.33 RADIO FREQUENCY INTERFERENCE

Radio frequency interference (RFI) is a general term frequently used to describe electromagnetic interference over a wide range of frequencies across the spectrum. RFI can be especially troublesome at low signal levels, but it may also affect higher level measurements in extreme cases.

RFI can be caused by steady-state sources such as TV or radio broadcast signals, or it can result from inpulse sources, as in the case of arcing in high voltage environments. In either case, the effect on instrument performance can be considerable, if enough of the unwanted signal is present. The effects of RFI can often be seen as an unusually large offset, or, in the case of impulse sources, sudden, erratic variations in the reading.

The most convenient method to minimize the effects of RFI is to use the FILTER feature of the Source Measure Unit. Up to 32 readings can be averaged with this filter. A detrimental affect of filtering is that overall Source Measure Unit speed is decreased.

Other methods can be used to minimize the effects of RFI. The most obvious method is to keep the instrument and experiment as far away from the RFI source as possible. Shielding the instrument, experiment, and test leads will often reduce RFI to an acceptable level. In extreme cases, a specially constructed screen room may be necessary to sufficiently attenuate the troublesome signal.

2.34 GROUND LOOPS

In general, optimum safety, shielding and stability are obtained by connecting OUTPUT LO to earth ground by installing the ground link on the rear panel of the Source Measure Unit. However, ground loops that occur in multiple-unit test set-ups can create error signals that cause erratic or erroneous performance. The configuration shown in Figure 2-80 shows a ground loop that is created by connecting OUTPUT LO to earth ground at two points. A large ground current flowing in the loop will encounter small resistances, either in the conductors, or at the connecting points. This small resistance results in voltage drops that can affect performance.

To prevent ground loops, the test system should be connected to ground at only a single point, as shown in Figure 2-81. Note that only the first Source Measure Unit is connected directly to power line ground (via ground link). Experimentation is the best way to determine an acceptable arrangement. For semiconductor characterization tests, best stability is usually obtained by connecting the Source Measure Unit used to supply power to the base (or gate) of the DUT to earth ground.

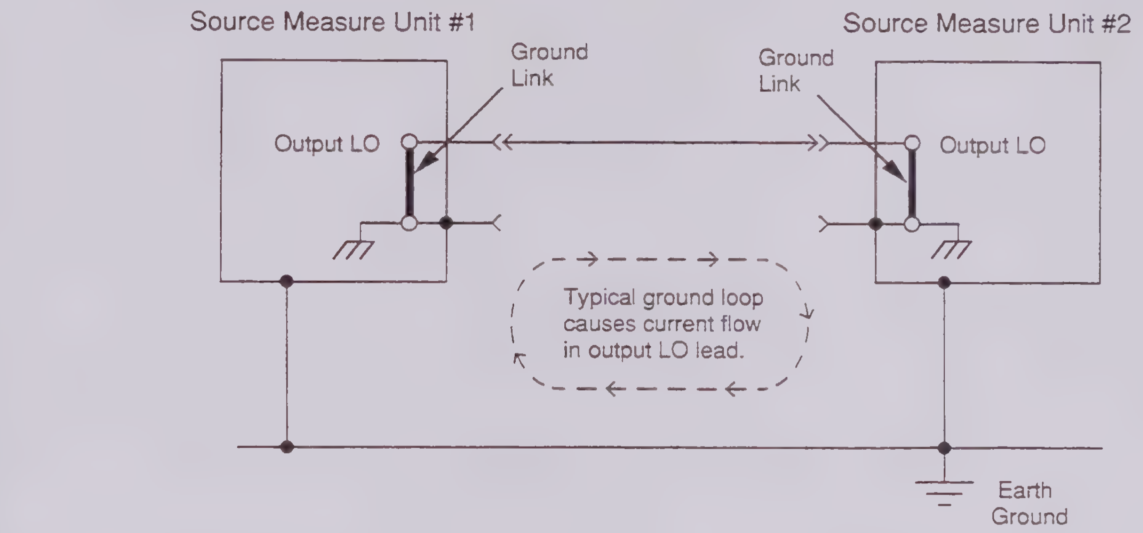

Source Measure Unit #1
Ground
Link
Output LO
Source Measure Unit #2
Ground
Link
Output LO
Typical ground loop
causes current flow
in output LO lead.
Earth
Ground

Figure 2-80. Multiple Ground Points Create Ground Loop

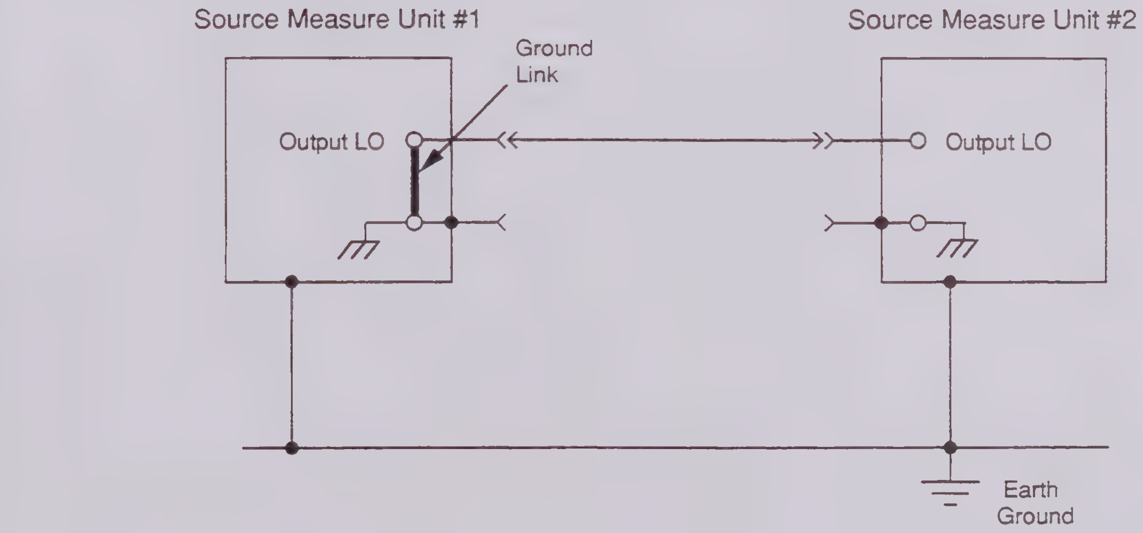

Source Measure Unit #1
Ground
Link
Output LO
Source Measure Unit #2
Output LO
Earth
Ground

Figure 2-81. Eliminating Ground Loop

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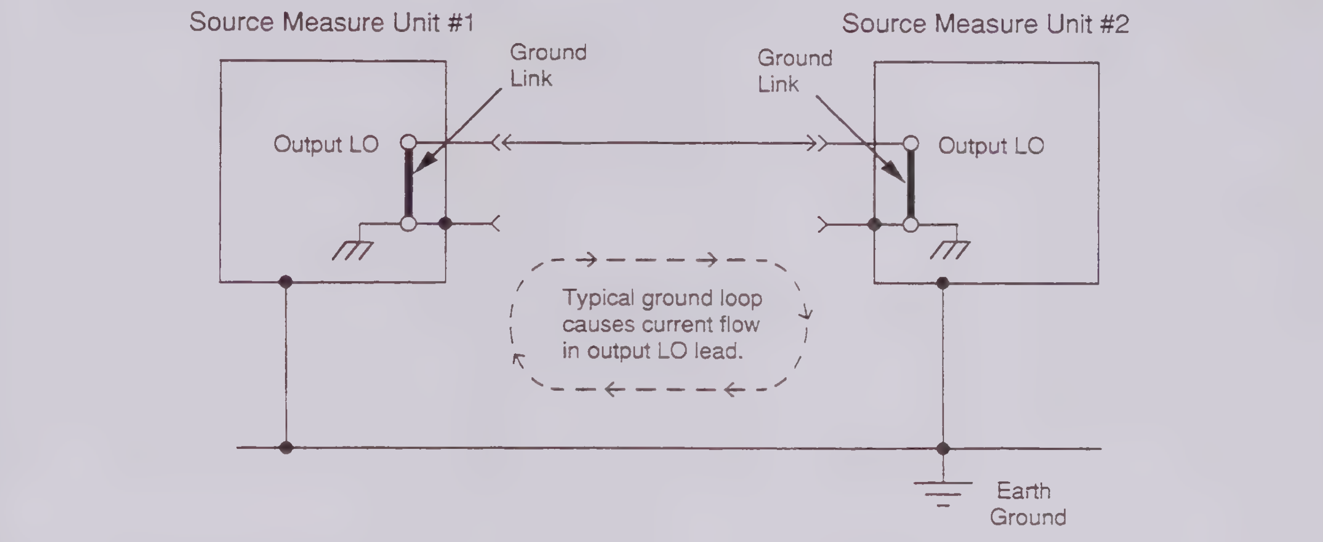
Source Measure Unit #1
Ground Link
Output LO
Source Measure Unit #2
Ground Link
Output LO
Typical ground loop causes current flow in output LO lead.
Earth Ground

Figure 2-80. Multiple Ground Points Create Ground Loop

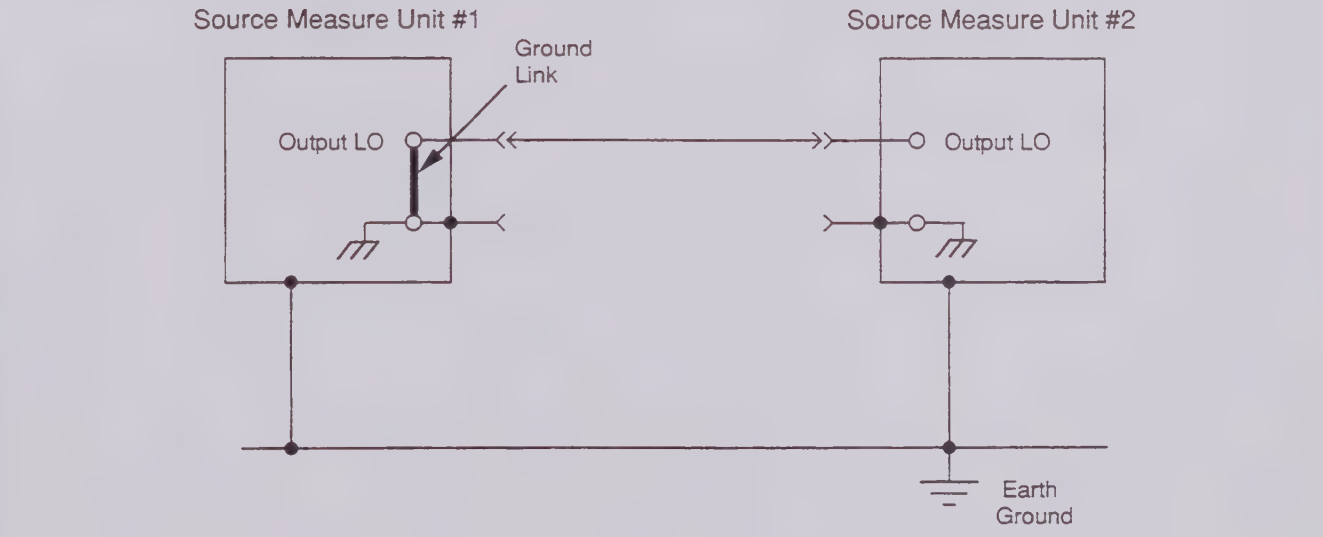
Source Measure Unit #1
Ground Link
Output LO
Source Measure Unit #2
Output LO
Earth Ground

Figure 2-81. Eliminating Ground Loop

SECTION 3
IEEE-488 Reference

3.1 INTRODUCTION
3.2 PRIMARY ADDRESS PROGRAMMING
3.3 CONTROLLER PROGRAMMING
3.4 FRONT PANEL ASPECTS OF IEEE-488 OPERATION
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3.5.5 DCL (Device Clear)
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SECTION 3
IEEE-488 Reference

3.1 INTRODUCTION

The IEEE-488 bus is an instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975 and given the IEEE-488 designation. In 1978, standards were upgraded into the IEEE-488-1978 standards. The Models 236, 237, and 238 conform to these standards.

This section contains reference information on programming the Model 236/237/238 over the IEEE-488 bus. Detailed instructions for all programmable functions are included, however, information concerning operating modes presented elsewhere is not repeated. Refer to Sections 1 and 2 for information not found in this section.

General information on the IEEE-488 bus is located in Appendix E.

3.2 PRIMARY ADDRESS PROGRAMMING

The Model 236/237/238 must receive a listen command before responding to addressed commands. Similarly, the unit must receive a talk command before transmitting data. The Models 236 , 237, and 238 are shipped from the factory with a programmed primary address of 16.

The primary address may be set to any value between 0 and 30 as long as address conflicts with other instruments are avoided. Note that controllers are also given a primary address, so do not use that address either. Most frequently, controller addresses are 0 or 21, but you should consult the controller's instruction manual for details. Whatever primary address you choose, you must make certain that it corresponds with the value specified as part of the controller's programming language.

To check the present primary address or to change to a new one, perform the following procedure:

1. Press the MENU button, then rotate the knob until the current primary address is displayed. For example, if the instrument is set to primary address 16, the following message will be displayed:

   16 IEEE ADDR

2. To retain the current address, press MENU to exit from the menu.
3. To change the primary address, use the numeric buttons and press ENTER. This stores the new address in memory so that the instrument powers up to that address. Then press MENU to exit.

NOTE

Each device on the bus must have a unique primary address. Failure to observe this precaution will probably result in erratic bus operation.

3.3 CONTROLLER PROGRAMMING

The programming instructions covered in this section use examples written with Hewlett Packard BASIC version 4.0. This language was chosen because of its versatility in controlling the IEEE-488 bus. This section covers those statements that are essential to Model 236/237/238 operation.

NOTE
Controller programming information for using the IBM PC interfaced through the Capital Equipment Corporation (CEC), I/O Tech, and National IEEE-488 interfaces is located in Appendix D.

A partial list of HP BASIC 4.0 statements is shown in Table 3-1. The statements have a one or three digit argument that must be specified. The first digit is the interface select code, which is set to 7 at the factory. The last two digits of those statements requiring a 3-digit argument specify the primary address.

Those statements with a 3-digit argument show a primary address of 16 (the factory default primary address of the Model 236/237/238). For a different address, you would, of course, change the last two digits to the required value. For example, to send a GTL command to a device using a primary address of 17, the following statement would be used: LOCAL 717.

Some of the statements have two forms; the exact configuration depends on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command, while CLEAR 716 sends the SDC command to a device with a primary address of 16.

3.4 FRONT PANEL ASPECTS OF IEEE-488 OPERATION

The following paragraphs discuss aspects of the front panel that are part of IEEE-488 operation, including messages, status indicators, and the LOCAL key.

Table 3-1. HP BASIC 4.0 IEEE-488 Statements

Action	BASIC Statement
Transmit string to device 16.	OUTPUT 716;A$
Obtain string from device 16.	ENTER 716;A$
Send GTL to device 16.	LOCAL 716
Send SDC to device 16.	CLEAR 716
Send DCL to all devices.	CLEAR 7
Send remote enable.	REMOTE 7
Cancel remote enable.	LOCAL 7
Serial poll device 16.	SPOLL (716)
Send local lockout.	LOCAL LOCKOUT 7
Send GET to device 16.	TRIGGER 716
Send IFC.	ABORT 7

3.4.1 Front Panel Messages

The Model 236/237/238 has a number of front panel messages. These messages, which are listed in Table 3-2, inform you of certain conditions that occur when sending device-dependent commands to the instrument or when using the front panel.

Pressing a front panel button will remove the existing error or warning message and any pending messages. If no buttons are pressed, the message is displayed for 0.8sec.

The following paragraphs describe the front panel messages associated with IEEE-488 programming. Note that the instrument may be programmed to generate an SRQ, and U command status words can be checked for specific error conditions if any of these errors occur. See paragraphs 3.6.11 and 3.6.19.

IDDC (Illegal Device-dependent Command) Error

An IDDC error occurs when the unit receives an illegal device-dependent command over the bus. For example, the command string IX includes an illegal command because "I" is not part of the instrument's programming language. When an illegal command is received, the instrument briefly displays the IDDC error message.

NOTE
When an IDDC error is detected in a command string, all commands in the string, up to and including the next X, are ignored.

Table 3-2. Front Panel Messages

Message	Description
BUFFER FILLED	Number of generated sweep points exceeds the buffer capacity.
CAL ADC GAIN, CAL ADC ZERO, CAL SRC GAIN, CAL SRC ZERO	Newly calculated cal constant is out of expected range for A/D converter gain, A/D converter zero, source gain, or source zero; a default cal constant value is substituted.
CAL COMPLI	Compliance reached during calibration.
CAL CONSTANTS ERR	Power-up verification of cal constants finds one or more values outside of predetermined limits; default value(s) used for those out of limits.
CAL INVALID ERR	One or more cal errors present on power-up, DCL, or SDC.
CAL MODE ERR	Error in calibrating common mode adjustment.
CAL VALUE ERR	Entered cal constant out of expected range for present step; check exponent and re-enter.
DPRAM LINK ERR	Communication error in the dual port RAM between the I/O controller and source/measure controller. Unit is not functional.
DPRAM LOCKUP	ROM or RAM failure in source/measure controller so it is not responding to I/O controller. Unit is not functional.
GENERATING SWEEP	Unit is creating or appending a sweep from the front panel.
IDDC	Unit received an illegal device-dependent command.
IDDCO	Unit received an illegal device-dependent command option.
ILLEGAL MEAS RANGE	Selected measure range is incompatible with source (V or I) or unit (236, 237 or 238).
ILLEGAL SRC RANGE	Selected source range is incompatible with source (V or I) or unit (236, 237 or 238).
IN CAL	You requested non-calibration commands while in calibration.
IN STBY	You requested a calibration command while in standby.
INTERLOCK PRESENT	You attempted to go into operate with an interlock condition present, or an interlock condition exists while in operate.
INVALID SWEEP MIX	Cannot create/append different sweep types (pulsed and non-pulsed) in buffer.
IOU CAL CHCKSUM	Power-up checksum test of cal constants failed.
IOU DPRAM FAILED	Dual port RAM in I/O controller failed. Unit is not functional.
IOU EEROM FAILED	Electrically erasable ROM in I/O controller failed.
LOG CANNOT CROSS 0	Cannot create/append a log sweep that passes through zero.
MEAS RANGE CHANGED	Cannot have source and measure ranges of 1100V and 100mA (237), or 110V and 1A (238) at same time; measurement range lowered.
MUST CREATE SWEEP	You attempted modifying, appending, or triggering a non-existent sweep.
NO AUTO IN PULSE	Cannot select source autoranging with a pulse sweep create or append.
NOT IN REMOTE	You sent an X command when the unit was not in remote (REN is false).
OFLO	An external power source has overloaded the measurement hardware in the Model 236/237/238.
PENDING TRIGGER	Unit was triggered while still processing a previous command; trigger will be processed.
PULSE TIME NOT MET	Specified pulse times (t_{ON} and t_{OFF}) might not be met and will be extended if necessary.
TEMPORARY CAL	CAL LOCK button is in LOCKED position; entered cal constants will not be saved if power is cycled.
TRIGGER OVERRUN	Unit was triggered while still processing a previous trigger; trigger is ignored.
UNCALIBRATED	No cal constants are stored in EEPROM (Source/Measure LED blinks).
VALUE OUT OF RANGE	Selected source value exceeds source range, or selected compliance value exceeds measurement range, or incremental source values are too small for selected range.
236 UNIT	You sent 1.1kV calibration commands to a Model 236.
65.000 SECONDS MAX	Cannot have a dc or sweep delay greater than 65.000 seconds. Value defaults to 65.000 seconds.
1F	Power-up or memory test of I/O controller RAM failed. Unit is not functional.
2F	Power-up or memory test of I/O controller ROM failed. Unit is not functional.

To correct error conditions, send only valid commands. Refer to paragraph 3.6 for device-dependent command programming details. Note that an IDDC error is also flagged in the U1 error status word, as discussed in paragraph 3.6.19.

Programming Example — To demonstrate an IDDC error, use the following statements:

```
REMOTE 716
OUTPUT 716;"IX"
```

The IDDC error message is briefly displayed when the second statement above is executed.

IDDCO (Illegal Device-dependent Command Option) Error

Sending the instrument a legal command with an illegal option results in the IDDCO error message being displayed.

For example, the command W2X has an illegal option (2) that is not part of the instrument's programming language. Thus, although the command W is valid, the option is not, and the IDDCO error results.

NOTE
When an IDDCO error is detected in a command string, all commands in the string, up to and including the next X, are ignored.

To correct this error condition, use only valid command options, as discussed in paragraph 3.6. Note that an IDDCO error is also flagged in the U1 error status word, as discussed in paragraph 3.6.19.

Programming Example — Demonstrate an IDDCO error with the following statements:

```
REMOTE 716
OUTPUT 716;"W2X"
```

Note that the IDDCO error message is briefly displayed when the second statement above is executed.

Not in Remote Error

A not in remote error occurs if the instrument receives an "X" while it is in the local state. The NOT IN REMOTE error message is displayed. This is caused by failing to set the REN line true before addressing the Model 236/237/238 to listen. (The HP9000 default is to set REN true.) The statement "REMOTE 7" sets the REN line true; the statement "REMOTE 716" sets the REN line true and addresses unit 16 to listen.

Programming Example — To demonstrate the NOT IN REMOTE error message, type in the following lines:

```
LOCAL 7
OUTPUT 716;"F0,0X"
```

Note that the NOT IN REMOTE error message is briefly displayed when the program times out.

Pending Trigger Condition

A pending trigger occurs when the unit is triggered while still processing a previous command (e.g., creating a sweep over the bus and receiving a front panel trigger). The trigger is saved until it can be acted upon and the READY FOR TRIGGER bit in the SPOLL byte is cleared.

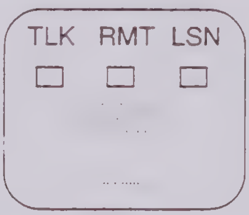
Trigger Overrun Error

A trigger overrun occurs when the instrument is triggered while it is still processing a source, delay, or measure phase from a previous trigger and before the READY FOR TRIGGER bit in the SPOLL byte is asserted. The exact trigger stimulus depends on the selected trigger source, as discussed in paragraph 3.6.18.

Overrun triggers do not affect the instrument except to generate the error message. In other words, the present sweep is not aborted by the overrun trigger stimulus and the trigger is ignored. When such a trigger overrun condition occurs, the instrument briefly displays the TRIGGER OVERRUN message.

3.4.2 IEEE-488 Status Indicators

The TLK (talk), RMT (remote), and LSN (listen) indicators show the present IEEE-488 status of the instrument. Each of these indicators is briefly described below.



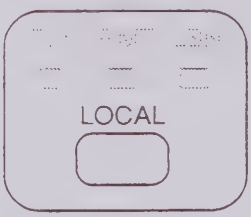
TLK — This indicator is on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk with the correct MTA (My Talk Address) command. TLK is off when the unit is in the talker idle state. The instrument is placed in the talker idle state by sending it an UNT (Untalk) command, addressing it to listen, or with the IFC (Interface Clear) command.

RMT — As the name implies, this indicator shows when the instrument is in the remote state. Note that RMT does not necessarily indicate the state of the REN line, as the instrument must be addressed to listen with REN true before the RMT indicator turns on. When the instrument is in remote, all front panel keys except for the LOCAL key are locked out. When RMT is turned off, the instrument is in the local state, and front panel operation is restored.

LSN — This indicator is on when the Model 236/237/238 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. Listen is off when the unit is in the listener idle state. The unit can be placed in the listener idle state by sending UNL (Unlisten), addressing it to talk, or by sending IFC (Interface Clear) over the bus.

3.4.3 LOCAL Key

The LOCAL key cancels the remote state and restores local operation of the instrument.



Since all front panel keys except LOCAL are locked out when the instrument is in remote, this key provides a convenient method of restoring front panel operation. Pressing LOCAL also turns off the RMT indicator, and returns the display to normal if a message was displayed with the D command. (See paragraph 3.6.4.)

Note that the LOCAL key is also inoperative if the LLO (Local Lockout) command is in effect.

3.5 GENERAL BUS COMMANDS

General bus commands are those commands such as DCL that have the same general meaning regardless of the instrument. Commands supported by the Model 236/237/238 are listed in Table 3-3 which also lists BASIC statements necessary to send each command. Note that commands requiring that a primary address be specified assume that the primary address is set to 16 (the default address of the Model 236/237/238).

Table 3-3. General Bus Commands and Associated BASIC Statements

Command	HP BASIC 4.0 Statement	Effect on Model 236/237/238
REN	REMOTE 7	Goes in effect when next addressed to listen.
IFC	ABORT 7	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	LOCAL key locked out.
GTL	LOCAL 716	Cancel remote, restore front panel operation.
DCL	CLEAR 7	Returns to power-up default conditions.
SDC	CLEAR 716	Returns to power-up default conditions.
GET	TRIGGER 716	Triggers next phase of S-D-M cycle if GET is selected as trigger origin.

3.5.1 REN (Remote Enable)

The remote enable command is sent to the Model 236/237/238 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true does not actually place the instrument in the remote state. Instead the instrument must be addressed to listen after setting REN true before it goes into remote.

Note that the instrument need not be in remote to be a talker.

Programming Example — This sequence is automatically performed by the controller when the following is typed into the keyboard.

```
REMOTE 716
```

After the RETURN key is pressed, the instrument is in the remote state, as indicated by the RMT light. If not, check to see that the instrument is set to the proper primary address 16, and check to see that the bus connections are properly made.

Note that all front panel controls except for LOCAL (and, of course, POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

3.5.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 236/237/238 in the local, talker and listener idle states. The unit responds to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of those states.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100µsec.

Programming Example — Before demonstrating the IFC command, turn on the TLK indicator with the following statement:

```
ENTER 716;A$
```

At this point, the TLK light should be on. The IFC command can be sent by entering the following statement into the computer:

```
ABORTIO 7
```

After the RETURN key is pressed, the TLK indicator turns off, indicating that the instrument has gone into the talker idle state.

3.5.3 LLO (Local Lockout)

The LLO command is used to prevent local operation of the instrument. After the unit receives LLO, all its front panel controls except POWER are inoperative.

Programming Example — The LLO command is sent by entering the following statements:

```
REMOTE 716
LOCAL LOCKOUT 7
```

After the second statement is executed, the instrument's front panel controls are locked out, including the LOCAL key.

To restore front panel operation after asserting LLO, as in the following example, enter:

```
LOCAL 7
```

3.5.4 GTL (Go To Local) and Local

The GTL command is used to take the instrument out of the remote state. Operation of the front panel keys will also be restored by GTL unless LLO is in effect. To cancel LLO, you must set REN false.

Programming Example — Place the instrument in the remote state with the following statement:

```
REMOTE 716
```

Now send GTL with the following statement:

```
LOCAL 716
```

Note that the instrument goes into the local state, and that operation of the front panel keys has now been restored (assuming that LLO is not in effect).

3.5.5 DCL (Device Clear)

The DCL command may be used to clear the Model 236/237/238 and return it to its power-up default conditions (see Table 3-4). Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 236/237/238 receives a DCL command, it returns to the power-up default conditions. DCL does not affect the programmed primary address.

Programming Example — Place the unit in an operating mode that is not a power-up default condition. Now enter the following statement from the controller keyboard:

```
CLEAR 7
```

When the RETURN key is pressed, the instrument returns to the power-up default conditions.

3.5.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL. When the Model 236/237/238 receives the SDC command, it returns to the power-up default conditions.

Programming Example — Place the unit in an operating mode that is not a power- up default condition. Now enter the following statement from the controller keyboard:

```
CLEAR 716
```

This sends the following IEEE-488 commands: UNT UNL LISTEN 16 SDC. When the statement is executed, the instrument executes its power-up sequence and returns to the power-up default configuration.

3.5.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 236/237/238 trigger if the instrument is placed in the appropriate trigger origin. More information on triggering is located in paragraph 3.6.

Programming Example — With triggers enabled, type in the following statements to place the instrument in the correct trigger origin for purposes of this demonstration:

```
REMOTE 716
OUTPUT 716;"T1,0,0,0X"
```

Program a sweep with the following statements.

```
OUTPUT 716; "F0,1X"
OUTPUT 716; "Q1,1,10,1,2,100X"
```

Now trigger the sweep by sending GET with the following statement:

```
TRIGGER 716
```

This sends IEEE-488 commands UNT UNL LISTEN 16 GET. When the RETURN key is pressed, the source-delay-measure cycle is triggered. (The command TRIGGER 7 just sends GET. Any other listeners are triggered when the RETURN key is pressed.)

3.5.8 SPE, SPD (Serial Polling)

The serial polling sequence is used to obtain the Model 236/237/238 serial poll byte. The serial poll byte contains important information about internal functions, as described in paragraph 3.6.11. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the Model 236/237/238.

Programming Example — The SPOLL statement automatically performs the serial poll sequence. To demonstrate serial polling, enter in the following statements into the computer:

```
S=SPOLL (716)
PRINT "SPOLL BYTE=";S
```

After the first statement, the controller conducts the serial polling sequence, After the second statement is executed, the decimal value of the serial poll byte is displayed on the controller CRT.

Table 3-4. Factory Initialization, Power-up, and DCL/SDC Conditions

	Factory Default	Power-up, DCL/SDC Default
Autorange (Measure)	Disabled	√
Bias (dc function)		
Source value	0V/0mA	√
Source range	11V (236, 237); 15V (238) / 10mA	√
Dc delay value	0msec	√
Calibration Step**	0	0
Compliance		
Value	10mA/10V	√
Range	10mA/11V (236, 237); 15V (138)	√
Default delay	Enabled	√
EOI and bus hold-off**	EOI enabled, hold-off on X	EOI enabled, hold-off on X
Filter	Disabled	√
Function	dc	dc
1100V Range Control**		
236/238	Disabled	Disabled
237	Enabled	√
IEEE address*	√	√
∫ Time	Fast period (416μsec)	√
Line frequency*	√	√
Operate/standby	Standby	Standby
Output format**		
Items	Source value only	Source value only
Format	ASCII with prefix and suffix	ASCII with prefix and suffix
Lines	1 line of dc data	1 line of dc data
Output Sense	Local	Local
Source	V-source	√
SRQ**		
Mask	None	None
Compliance	SRQ during idle, measure or delay phase	SRQ during idle, measure or delay phase

√User's previously programmed condition *Front panel only **IEEE-488 Bus only

Factory Initialization, Power-up, and DCL/SDC Conditions (Cont.)

	Factory Default	**Power-up, DCL/SDC Default**
Stored ASCII String**	√	√
Suppression		
Control	Disabled	Disabled
Value	0V, 0mA	0V, 0mA
Sweep buffer	Cleared	Previous sweep data retained
Sweep create/append	Linear stair	√
Start value	1V/1mA	√
Stop value	10V/10mA	√
Source range	11V (236, 237); 15V (238) / 10mA	√
Delay time	0msec	√
Number of Points (Pulses)	10	√
Step value	1V/1mA	√
Log points	10 points/decade	√
Pulse on time	100msec	√
Pulse off time	100msec	√
Sweep modify	First point*	First point*
Terminators**	CR LF	CR LF
Trigger configuration		
Origin	Internal (Immediate)	√
Trig in	Continuous	√
Trig out	None	√
Sweep End	Disabled	√
Trigger control	Enabled	Enabled

Device-dependent Commands

3.6 DEVICE-DEPENDENT COMMAND PROGRAMMING
3.6.1 A — Modify Sweep List
3.6.2 B — Bias
3.6.3 C — Calibration
3.6.4 D — Display
3.6.5 F — Source and Function
3.6.6 G — Output Data Format
3.6.7 H — IEEE Immediate Trigger
3.6.8 J — Self-tests
3.6.9 K — EOI and Bus Hold-Off
3.6.10 L — Compliance
3.6.11 M — SRQ Mask and Serial Poll Byte Format
3.6.12 N — Operate
3.6.13 O — Output Sense
3.6.14 P — Filter
3.6.15 Q — Create/Append Sweep List
3.6.16 R — Trigger Control
3.6.17 S — Integration Time
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3.6.19 U — Status
3.6.20 V — 1100V Range Control
3.6.21 W — Default Delay
3.6.22 X — Execute
3.6.23 Y — Terminator
3.6.24 Z — Suppress
3.7 TIMING CONSIDERATIONS
3.7.1 Factors Affecting Sweep Times
3.7.2 Optimizing Source and Measurement Speed
3.7.3 Estimating Sweep Performance
3.7.4 Estimating dc Performance

Model 236/237/238 Device-dependent Commands

Modify Sweep List

A(level),(range),(delay),first(,last)

level — Output level of sweep source:

I-source	(236, 237)	–100.00 to +100.00mA
	(238)	–1.0000 to +1.0000A
V-source	(236, 238)	–110.00 to +110.00V
	(237)	–1100.0 to +1100.0V

range — Source range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V(237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option.

delay — Sweep delay in msec (0-65000)
first — First data point (1-1000)
last — Last data point (1-1000)

Bias Operation

B(level),(range),(delay)

level — Output level of dc source:

I-source	(236, 237)	–100.00 to +100.00mA
	(238)	–1.0000 to +1.0000A
V-source	(236, 238)	–110.00 to +110.00V
	(237)	–1100.0 to +1100.0V

range — Source range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option

delay — Dc delay in msec (0-65000)

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(216) 248-0400

Operate

N0	Standby
N1	Operate

Output Sense

O0	Local sense
O1	Remote sense

Filter

P0	Filter disabled
P1	2 readings
P2	4 readings
P3	8 readings
P4	16 readings
P5	32 readings

Create/Append Sweep List

Q0,(level),(range),(delay),(count)
  Create fixed level sweep
Q1,(start),(stop),(step),(range),(delay)
  Create linear stair sweep
Q2,(start),(stop),(points),(range),(delay)
  Create logarithmic stair sweep
Q3,(level),(range),(pulses),(t_{ON}),(t_{OFF})
  Create fixed level pulsed sweep
Q4,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})
  Create linear stair pulsed sweep
Q5,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})
  Create logarithmic stair pulsed sweep

Q6,(level),(range),(delay),(count)
  Append fixed level sweep
Q7,(start),(stop),(step),(range),(delay)
  Append linear stair sweep
Q8,(start),(stop),(points),(range),(delay)
  Append logarithmic stair sweep
Q9,(level),(range),(pulses),(t_{ON}),(t_{OFF})
  Append fixed level pulsed sweep
Q10,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})
  Append linear stair pulsed sweep
Q11,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})
  Append logarithmic stair pulsed sweep

count — Number of S-D-M cycles in sweep (1-1000)

delay — Sweep delay in msec (0-65000)

Create/Append Sweep List (Cont.)

level — Output level of sweep source:

I-source	(236, 237)	–100.00 to +100.00mA
	(238)	–1.0000 to +1.0000A
V-source	(236, 238)	–110.00 to +110.00V
	(237)	–1100.0 to +1100.0V

points — Logarithmic points per decade:
0 = 5 points/decade
1 = 10 points/decade
2 = 25 points/decade
3 = 50 points/decade

pulses — Pulse quantity (0-500)

range — Source range:

	I-source	V-source
0 =	Auto (no pulsed sweeps)	Auto (no pulsed sweeps)
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1μA	1100V (237)
5 =	10μA	*
6 =	100μA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option.

start, stop — Start and stop source values for stair sweeps.

I-source	(236, 237)	–100.00 to +100.00mA
	(238)	–1.0000 to +1.0000A
V-source	(236, 238)	–110.00 to +110.00V
	(237)	–1100.0 to +1100.0V

step — Incremental absolute value for stair sweeps.

I-source	(236, 237)	–200.00 to +200.00mA
	(238)	–2.0000 to +2.0000A
V-source	(236, 238)	–220.00 to +220.00V
	(237)	–2200.0 to +2200.0V

t_{ON} — Duration of sweep level in msec (0-65000)
t_{OFF} — Duration of bias level in msec (0-65000)

Trigger Control

R0	Disable input triggering and generation of output triggers
R1	Enable input triggering and generation of output triggers

Integration Time

S0	416μsec integration time, Fast, 4-digit resolution
S1	4msec integration time, Medium, 5-digit resolution
S2	16.67msec integration time, 60Hz ac line, 5-digit resolution
S3	20msec integration time, 50Hz ac line, 5-digit resolution

Trigger Configuration

T(origin),(in),(out),(end)

origin — Input trigger origin:
0 = IEEE X
1 = IEEE GET
2 = IEEE Talk
3 = External (TRIGGER IN pulse)
4 = Immediate only (MANUAL key or H0X command)

in — Input trigger effect:
0 = Continuous (no trigger needed to continue S-D-M)
1 = ^SRC DLY MSR (trigger starts source)
2 = SRC^DLY MSR (trigger starts delay)
3 = ^SRC^DLY MSR
4 = SRC DLY^MSR (trigger starts measure)
5 = ^SRC DLY^MSR
6 = SRC^DLY^MSR
7 = ^SRC^DLY^MSR
8 = ^Single Pulse

out — Output trigger generation:
0 = None during sweep
1 = SRC^DLY MSR (end of source)
2 = SRC DLY^MSR (end of delay)
3 = SRC^DLY^MSR
4 = SRC DLY MSR^ (end of measure)
5 = SRC^DLY MSR^
6 = SRC DLY^MSR^
7 = SRC^DLY^MSR^
8 = Pulse End^

end — Sweep End^ trigger out:
0 = Disabled
1 = Enabled

Status

U0	Send model number and firmware revision
U1	Send error status word
U2	Send stored ASCII string ("D2" command string)
U3	Send machine status word
U4	Send measurement parameters
U5	Send compliance value
U6	Send suppression value
U7	Send calibration status word
U8	Send defined sweep size
U9	Send warning status word
U10	Send first sweep point in compliance
U11	Send sweep measure size

1100V Range Control — 237 only

V0	Disable 1100V range
V1	Enable 1100V range

Default Delay

W0	Disable default delay
W1	Enable default delay

Execute

X	Execute commands

Terminator

Y0	<CR><LF>
Y1	<LF><CR>
Y2	<CR>
Y3	<LF>
Y4	none

Suppress

Z0	Disable suppression
Z1	Enable suppression

Device-dependent Commands

3.6 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are the most important commands associated with instrument programming because they control most instrument operating modes. The IEEE-488 bus actually treats these commands as data, in that they are sent with the ATN line false.

All Model 236/237/238 front panel operations (such as trigger configuration and creating sweep lists), as well as some operations not available from the front panel (like SRQ and terminator) can be programmed with these commands.

Command Syntax — Each command is made up of a single ASCII capital letter followed by one or more numbers or letters representing an option or numeric parameter of that command. For example, the integration time can be set over the bus by sending the letter "S" followed by a number representing the integration time option. S0X would be sent to program a 416μsec integration time.

Some commands have two or more parameters that must be separated by commas. For example, a T4,0,0,0X command programs a trigger configuration. In this case, the 4 selects a trigger origin, while the 0 parameters select what effect an input trigger has on the instrument, when an output trigger is generated by the unit, and whether an output trigger is generated at the end of sweep.

Parameter values for output, measured, and compliance levels can be designated either of two ways, even within the same command:

- Scientific notation, or exponent form, where 5E–3 represents 5mV or 5mA.
- Real numbers, where .005 represents 5mV or 5mA.

In both cases, entered values are truncated to five significant digits. Only as many significant digits as necessary need be used. (Send 1.9E–6 instead of 1.9000E–06.)

Multiple Commands — A number of commands can be grouped together in one command string, which is generally terminated by the "X" character. This character tells the instrument to execute the command or command string, as described in paragraph 3.6.22. Commands sent without the execute character will not be executed at that particular time, but they will be stored within an internal command buffer for later execution when the execute character is finally received.

Invalid Commands — If an invalid command is sent as part of the command string, no commands in the string will be executed. Under these conditions, the instrument will display a front panel error message (IDDC or IDDCO) and it can be programmed to generate an SRQ (Service Request), as discussed in paragraph 3.6.11. Note, however, that the instrument does not check the validity of commands until the X character is received.

Some typical examples of valid command strings include:

R0X	Single command followed by execute command.
Y4S0P0X	Multiple command string.
Z 1X	Space is ignored,
T4,0,0,0X	Multiple-parameter command string (parameters separated by commas).

Typical invalid command strings include:

E1X	Invalid command, as E is not one of the instrument's valid commands.
K4X	Invalid command option because 4 is not an option of the K command.
L1101,4X	Invalid parameter (maximum compliance level is 100mA or 1100V).
T4000X	Multiple-parameter command without the necessary separating commas.

Using Multiple-Option Commands — Some commands have multiple options, allowing you to program several parameters with a single command letter. For example, the Q command is used to program a sweep waveform, and the parameters associated with that waveform, as in the following example:

Q1,(start),(stop),(step),(range),(delay)

The general format for listing multiple-option commands in this manual is as follows:

1. Required parameters are shown without parentheses. For instance, the Q command requires a number to designate a sweep type (the parameter "1" in the Q1 command). Omission of a number in this position causes an IDDCO.
2. Optional parameters are shown within parentheses ("start", "stop", "step", "range", and "delay" in the Q1 command). Do not include parentheses in actual command strings.

3. Commas are required delimiters, except as noted in the A and C commands. Omission of any of the five commas in the Q1 command causes an IDDCO. For example, to change only a step value while leaving the start, stop, range, and delay values unchanged, the following command string would be used:

   Q1,,,2,,X

   In this case, the commas mark positions where the start, stop, range, and delay values are omitted.

Order of Command Execution — Device-dependent commands are not necessarily executed in the order received. Rather, the instrument always executes them in a specific order, as summarized in Table 3-5.

Table 3-5. Order of Command Execution

Order	Command	Description
1	M	Set the SRQ mask
2	C	Calibration sequence
3	F	Set source and function
4	O	Program local/remote sense
5	P	Select filter
6	Z	Program suppression
7	S	Set integration time
8	W	Enable/disable default delay
9	L	Program compliance
10	B	Program bias operation
11	Q	Create/append sweep list
12	A	Modify sweep list
13	T	Select trigger configuration
14	R	Enable/disable triggers
15	N	Select operate/standby mode
16	D	Display a user message
17	Y	Select terminator characters
18	K	Select EOI and hold-off on X
19	G	Select output data format
20	V	1100V range control
21	J	Execute self-tests
22	U	Request status
23	H	Send IEEE immediate trigger
24	X	Execute DDCs

If you wish to force a particular order of execution, simply include the execute (X) character after each command-option grouping in the command string. For example, the following string would be executed in the received order:

R0XF1,1R1N1H0X

If the previous statements did not have an X immediately following R0, the R0 command would not have been executed, because the Model 236/237/238 will execute the last received option for repeated commands in the same string.

Device-dependent Command Summary — All Model 236/237/238 device-dependent commands are summarized in Table 3-6, which also lists respective paragraphs where more detailed information on each command may be found.

Table 3-6. Device-dependent Command Summary

Mode	Command	Description	Para.
Modify Sweep List	A(level),(range),(delay),first(,last)	Modify sweep list points	3.6.1
Bias Operation	B(level),(range),(delay)	Select bias operation	3.6.2
Calibration	C step (,value) X	Calibrate instrument	3.6.3
Display	D0X	Return display to normal	3.6.4
	D1,aaa...aX	Display ASCII characters (18 max.)	
	D2,aaa...aX	Display and store ASCII characters (18 max.)	
Source and Function	F(source),(function)	Select source (V or I) and function (dc or sweep)	3.6.5
Output Data Format	G(items),(format),(lines)	Select items included, format, and lines per talk in output	3.6.6
IEEE Immediate Trigger	H0X	Cause an immediate bus trigger	3.6.7
Self-tests	J0X	Restore factory defaults	3.6.8
	J1X	Perform memory test	
	J2X	Perform display test	
EOI and Bus Hold-off	K0	Enable EOI, enable hold-off on X	3.6.9
	K1	Disable EOI, enable hold-off on X	
	K2	Enable EOI, disable hold-off on X	
	K3	Disable EOI, disable hold-off on X	
Compliance	L(level),(range)	Set compliance level and range	3.6.10
SRQ Mask and Serial Poll Byte	M(mask),(compliance)	Select conditions that will cause a service-request	3.6.11
Operate	N0	Place unit in standby mode	3.6.12
	N1	Place unit in operate mode	
Output Sense	O0	Select local sensing	3.6.13
	O1	Select remote sensing	
Filter	P0	Measurement filter disabled	3.6.14
	P1	2-reading filter	
	P2	4-reading filter	
	P3	8-reading filter	
	P4	16-reading filter	
	P5	32-reading filter	
Create/Append Sweep List	Q0,(level),(range),(delay),(count)	Create fixed level sweep	3.6.15
	Q1,(start),(stop),(step),(range),(delay)	Create linear stair sweep	
	Q2,(start),(stop),(points),(range),(delay)	Create logarithmic stair sweep	
	Q3,(level),(range),(pulses),(t_{ON}),(t_{OFF})	Create fixed level pulsed sweep	
	Q4,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})	Create linear stair pulsed sweep	
	Q5, (start),(stop),(points),(range),(t_{ON}),(t_{OFF})	Create logarithmic stair pulsed sweep	

Device-dependent Command Summary (Cont.)

Mode	Command	Description	Para.
Create/Append Sweep List (Cont.)	Q6,(level),(range), (delay),(count)	Append fixed level sweep	3.6.15
	Q7, (start),(stop),(step), (range),(delay)	Append linear stair sweep	
	Q8,(start),(stop),(points), (range),(delay)	Append logarithmic stair sweep	
	Q9,(level),(range), (pulses),(t_{ON}),(t_{OFF})	Append fixed level pulsed sweep	
	Q10,(start),(stop),(step), (range),(t_{ON}),(t_{OFF})	Append linear stair pulsed sweep	
	Q11,(start),(stop), (points),(range),(t_{ON}), (t_{OFF})	Append logarithmic stair pulsed sweep	
Trigger Control	R0	Disable input/output triggers	3.6.16
	R1	Enable input/output triggers	
Integration Time	S0	416µsec integration time	3.6.17
	S1	4msec integration time	
	S2	16.67msec integration time	
	S3	20msec integration time	
Trigger Configuration	T(origin),(in),(out),(end)	Program input trigger origin and effects, output triggers, and end-of-sweep output trigger.	3.6.18
Status	U0	Send model no. and revision	3.6.19
	U1	Send error status word	
	U2	Send stored ASCII string	
	U3	Send machine status word	
	U4	Send measurement parameters	
	U5	Send compliance value	
	U6	Send suppression value	
	U7	Send calibration status word	
	U8	Send defined sweep size	
	U9	Send warning status word	
	U10	Send first sweep point in compliance	
	U11	Send sweep measure size	
1100V Range Control	V0	Disable 1100V range	3.6.20
	V1	Enable 1100V range	
Default Delay	W0	Disable default delay	3.6.21
	W1	Enable default delay	
Execute	X	Execute commands	3.6.22
Terminator	Y0	<CR><LF>	3.6.23
	Y1	<LF><CR>	
	Y2	<CR>	
	Y3	<LF>	
	Y4	None	
Suppress	Z0	Disable suppression	3.6.24
	Z1	Enable suppression	

3.6.1 A — Modify Sweep List

Purpose To change the source level, source range, or sweep delay of any points in a sweep list of a previously created or appended waveform.

Format **A(level),(range),(delay),first(,last)**

Parameters *level* — Specifies output level of sweep source (I or V):

I-source	(236/237)	–100.00 to +100.00mA
	(238)	–1.0000 to +1.0000A
V-source	(236/238)	–110.00 to +110.00V
	(237)	–1100.0 to +1100.0V

range — Selects the source range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option.

delay — Sweep delay in milliseconds (0-65000)

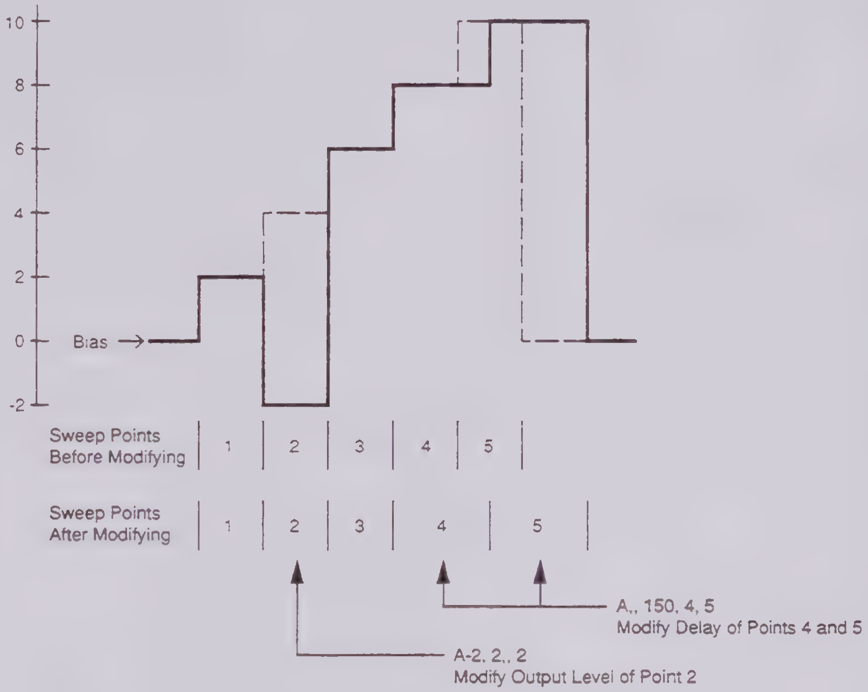
first — First data point (1-1000)

last — Last data point (1-1000)

Default Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selections. A J0X command restores factory default values for the first and last data points to "1". Note that "first" must always be specified.

Description The A command modifies a point or range of consecutive points in the sweep list. The specified parameters are used to replace the corresponding point in the sweep list from "first" through "last". If "last" is not specified, only the parameters selected by "first" are modified. Only the specified command parameters are used to modify the corresponding sweep list parameters.

Figure 3-1 shows the before/after modification of a linear stair sweep waveform with the program listed in the example below. The output level of point 2 is changed with one command, and the delays of points 4 and 5 are changed with another command.


10
8
6
4
2
0
-2
Bias →
Sweep Points Before Modifying
1
2
3
4
5
Sweep Points After Modifying
1
2
3
4
5
A,, 150, 4, 5
Modify Delay of Points 4 and 5
A-2, 2,, 2
Modify Output Level of Point 2

	Before Modifying		After Modifying	
Sweep Point	Source Value	Sweep Delay	Source Value	Sweep Delay
1	2V	100 msec	2V	100 msec
2	4V	100 msec	-2V	100 msec
3	6V	100 msec	6V	100 msec
4	8V	100 msec	8V	150 msec
5	10V	100 msec	10V	150 msec

Figure 3-1. Modify Sweep List

Programming Notes

1. Parameter "first" must always be specified; omission causes an IDDCO.
2. If parameter "last" is specified, a comma must precede it. If "last" is not specified, it's preceding comma is optional.
3. You can modify up to and including the last defined sweep point. An attempt to modify a non-existent sweep point is ignored. For example, an attempt to modify points 50-150 of a 100-point sweep yields a MUST CREATE SWEEP warning condition and the entire modify command is ignored.
4. In autorange, the source range is adjusted for the highest on-scale sourcing possible.
5. If the source range is not specified, the instrument will try to place the new source value on the present range. This could result in a VALUE OUT OF RANGE warning. Therefore, it is good practice to always specify a source range when modify-

ing the source value.

6. Use the sweep delay to compensate for any settling time required by the external circuit connected to the source-measure unit.
7. If a pulse sweep is modified, it's delay times will no longer be recalculated for changes in autorange measure, filtering, integration time, and default delay.
8. Depending on your controller and program, a bus timeout may occur during a long sweep delay. If you trigger a reading and ask for it right away, the bus is held off until the measurement is available, possibly causing a timeout.
9. Error and warning conditions for the A command are described in the U1 error status word and U9 warning status word (see paragraph 3.6.19).

Programming Example

```
10    REMOTE 716                      ! Set for IEEE-488 communication
20    OUTPUT 716;“F0,1X”              ! Source V, measure I, sweep
30    OUTPUT 716;“Q1,2,10,2,2,100X”   ! Linear stair sweep, five 2V steps,
                                        11V or 15V range, 100msec delay
40    OUTPUT 716;“A–2,2,,2X”          ! Change point 2 to –2V
50    OUTPUT 716;“A,,150,4,5X”        ! Change points 4 and 5 to
                                        150msec delay
60    END
```

3.6.2 B — Bias

Purpose

To program the dc bias operation, the non-triggered sweep source value, and the t_{OFF} source value of pulsed sweeps.

Format

B(level),(range),(delay)

Parameters

level — Specifies the dc bias level (I or V) to output:

I-source	(236/237)	−100.00 to +100.00mA
	(238)	−1.0000 to +1.0000A
V-source	(236, 238)	−110.00 to +110.00V
	(237)	−1100.0 to +1100.0V

range — Selects the bias range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option.

delay — The dc delay in milliseconds (0 to 65000)

Default

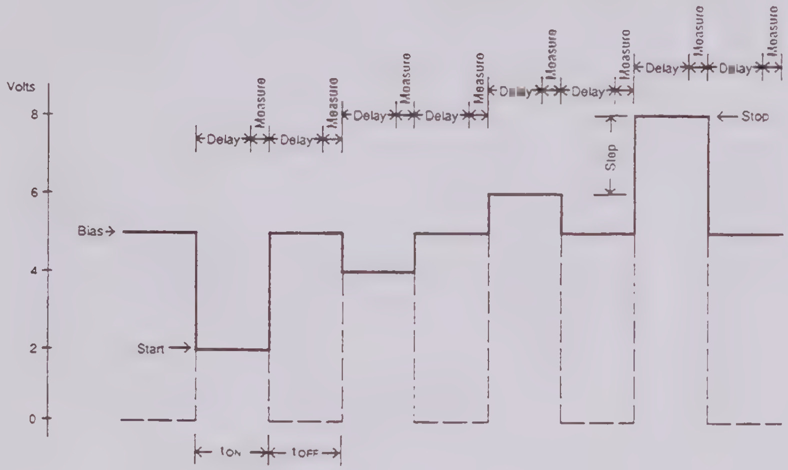
Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selections. A J0X command restores factory default values of 0V/0mA bias level, 11V or 15V/10mA range, and dc delay of 0msec.

Description

The B command sets the bias level of the instrument. When the Model 236/237/238 is programmed for dc operation (F command), the bias becomes the dc output level. When creating a sweep list (Q command), this command establishes the bias for the sweep. Refer to paragraph 3.6.5 for the F command and 3.6.15 for the Q command.

Command parameters include the bias level, bias range, and dc delay. The bias range applies whether in dc or sweep operation. For sweeps, the range parameter sets the bias range before and after sweeps and, for pulsed sweeps, during the t_{OFF} times. The specified delay is used in dc operation. If presently in sweep operation, the delay will be retained for use when in dc operation.

Figure 3-2 shows the effect of a bias command on a fixed level pulsed sweep. First the bias level is set with the B command, then the sweep is programmed with a Q4 command. The first example program lists the necessary commands to generate this waveform.



Sweep Point	Source Value	t_{ON}/t_{OFF}
1	2V	100 msec
2	5V	100 msec
3	4V	100 msec
4	5V	100 msec
5	6V	100 msec
6	5V	100 msec
7	8V	100 msec
8	5V	100 msec

```
B5, 2, 0
Q4, 2, 8, 2, 2,100,100
```

Figure 3-2. Bias Operation

Programming Notes

1. Set the bias value before programming a sweep so the desired bias is in effect when the create/append sweep (Q) command is executed. The B command should precede or reside in the same command string as the Q command, but not in a separate command string after the Q command.
2. If autoranging is not used for either the bias range or sweep range, they should be set to the same fixed range to prevent range changes during a sweep. Range changes affect sweep timing and, since the output level is momentarily set to [illegible] during a range change, could have an undesirable affect on the test in progress.
3. In autorange, the bias range is adjusted for the highest on-scale sourcing possible.
4. If the bias range is not specified, the instrument will try to place the new bias level on the present range. This could result in a VALUE OUT OF RANGE warning. Therefore, it is good practice to always specify a bias range when setting the bias level.
5. Use the dc delay to compensate for any settling time required by the external circuit connected to the source-measure unit.
6. Depending on your controller and program, a bus timeout may occur during a long dc delay. If you trigger a reading and ask for it right away, the bus is held off until the measurement is available, possibly causing a timeout.
7. If time stamping is desired, use a fixed level sweep instead of dc operation (see the Q0 command in paragraph 3.6.15).

8. Only terminator characters are sent if dc data is requested with the G command while the instrument is in the sweep function (see paragraph 3.6.6).
9. Error and warning conditions for the B command are described in the U1 error status word and U9 warning status word (see paragraph 3.6.19).

Programming Examples

```
10    REMOTE 716
20    OUTPUT 716;"F0,1X"                  ! Source V, sweep
30    OUTPUT 716;"B5,2,0X"                ! Set bias of 5V, 11V or 15V range.
40    OUTPUT 716;"Q4,2,8,2,2,100,100X"    ! Linear stair pulsed sweep, 2-8V,
                                            11V or 15V range, 100msec

10    OUTPUT 716;"F0,0X"                  ! Source V, dc
20    OUTPUT 716;"B5,2,500X"              ! 5V bias, 11V or 15V range,
                                            500msec delay
30    OUTPUT 716; "H0X"                   ! Trigger output
```

3.6.3 C — Calibration

Purpose To calibrate the Model 236/237/238 instrument.

Format **C step (,value) X**

Where:

step = command option number
value = measured or sourced calibration value

Parameters

C0X	Enter calibration procedure
C1X	Common mode adjustment
C2X	Set up +1.1V source and measure offset calibration
C3,VmsrX	Vmsr = Measured voltage
C4X	Set up +1.1V source and measure gain calibration
C5,VmsrX	Vmsr = Measured voltage
C6X	Set up –1.1V source and measure offset calibration
C7,VmsrX	Vmsr = Measured voltage
C8X	Set up –1.1V source and measure gain calibration
C9,VmsrX	Vmsr = Measured voltage
C10X	Set up +11V source and measure offset calibration
C11,VmsrX	Vmsr = Measured voltage
C12X	Set up +11V source and measure gain calibration
C13,VmsrX	Vmsr = Measured voltage
C14X	Set up –11V source and measure offset calibration
C15,VmsrX	Vmsr = Measured voltage
C16X	Set up –11V source and measure gain calibration
C17,VmsrX	Vmsr = Measured voltage
C18X	Set up +110V source and measure offset calibration
C19,VmsrX	Vmsr = Measured voltage
C20X	Set up +110V source and measure gain calibration
C21,VmsrX	Vmsr = Measured voltage
C22X	Set up –110V source and measure offset calibration
C23,VmsrX	Vmsr = Measured voltage
C24X	Set up –110V source and measure gain calibration
C25,VmsrX	Vmsr = Measured voltage

237/238 only

C26X	Set up +1.1kV (237) or +1A (238) source and measure offset calibration
C27,msrX	msr = Measured voltage (237) or current (238)
C28X	Set up +1.1kV (237) or +1A (238) source and measure gain calibration
C29,msrX	msr = Measured voltage (237) or current (238)

C30X	Set up –1.1kV (237) or –1A (238) source and measure offset calibration
C31,msrX	msr = Measure voltage (237) or current (238)
C32X	Set up –1.1kV (237) or –1A (238) source and measure gain calibration
C33,msrX	msr = Measured voltage (237) or current (238)
C34X	Set up +100mA source and measure offset calibration
C35,ImsrX	Imsr = Measured current
C36X	Set up +100mA source and measure gain calibration
C37,ImsrX	Imsr = Measured current
C38X	Set up –100mA source and measure offset calibration
C39,ImsrX	Imsr = Measured current
C40X	Set up –100mA source and measure gain calibration
C41,ImsrX	Imsr = Measured current
C42X	Perform 1nA measure offset calibration
C43,IsrcX	Perform 1nA measure gain calibration, Isrc = Sourced current
C44X	Perform 10nA measure offset calibration
C45,IsrcX	Perform 10nA measure gain calibration, Isrc = Sourced current
C46X	Perform 100nA measure offset calibration
C47,IsrcX	Perform 100nA measure gain calibration, Isrc = Sourced current
C48X	Perform 1μA measure offset calibration
C49,IsrcX	Perform 1μA measure gain calibration, Isrc = Sourced current
C50X	Perform 10μA measure offset calibration
C51,IsrcX	Perform 10μA measure gain calibration, Isrc = Sourced current
C52X	Perform 100μA measure offset calibration
C53,IsrcX	Perform 100μA measure gain calibration, Isrc = Sourced current
C54X	Perform 1mA measure offset calibration
C55,IsrcX	Perform 1mA measure gain calibration, Isrc = Sourced current
C56X	Perform 10mA measure offset calibration
C57,IsrcX	Perform 10mA measure gain calibration, Isrc = Sourced current
C58X	Perform 1nA to 10mA source calibration
C59X	Exit calibration procedure

Default

Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to C0 (calibration step zero).

Description

In general, the source ranges on the Model 236/237/238 are calibrated by measuring the voltage or current level applied by the Model 236/237/238. The values measured by a precision meter are sent to the source-measure unit within C commands. The measure ranges are calibrated by using the Model 236/237/238 to measure current applied by a precision source. The sourced values are sent to the source-measure unit within C commands.

Programming Notes

1. Each C command is sent separately and followed with an X.
2. Calibration step parameters must be explicitly declared; no defaults are allowed.
3. The U7 calibration status word indicates the calibration step in progress, the position of the CAL LOCK switch, and whether the unit is calibrated. (See paragraph 3.6.19.)
4. Error conditions for the C command are described in the U1 error status word (see paragraph 3.6.19).
5. Execution of the C command places the instrument in an untriggered state. During a calibration procedure (C0 through C59), the unit will ignore any triggers. If the instrument is triggered from the front panel while it is being calibrated, the PENDING TRIGGER message is displayed, but when the calibration procedure is ended with C59X, the sweep is not started.
6. The C1 through C59 commands will be ignored if the enter cal procedure (C0X) command was not sent first.
7. The present calibration constants will only be saved to non-volatile memory upon execution of C59X if the CAL LOCK button is in the unlocked position.
8. Entering the cal procedure with C0X will automatically set certain operating parameters for calibration without user intervention (e.g., integration time to line cycle). These changes will not be reflected in the U status words. Exiting from the cal procedure with C59X will return the parameters to the user-programmed settings.
9. The only commands permitted during a cal procedure are C (calibration), N (operate/standby), O (output sense), and U (status). All others will cause an error.
10. The reading done bit in the SRQ byte will be set after completion of a cal step. However, no measurement will be available for output.
11. Calibrating the 1100V range requires that the range is enabled with the V1 command (see paragraph 3.6.20).

Programming Example

CAUTION: The following examples are only to show proper syntax. Only send calibration commands when actually calibrating the instrument. A complete IEEE-488 calibration procedure is contained in the Model 236/237/238 Service Manual.

```
OUTPUT 716;"C0X"           ! Enter calibration
OUTPUT 716;"C1X"           ! Common mode adjustment
OUTPUT 716;"C2X"           ! Set up 1.1V offset cal.
OUTPUT 716;"C3,.001X"      ! Send measured offset
```

3.6.4 D — Display

Purpose

To display messages on the front panel.

Format

Dn,aaa...aX

Where:

n = command option number
a = ASCII character to display (18 maximum)

Parameters

D0X	Return display to normal operation.
D1,aaa...aX	Display characters "aaa", where "aaa" represents printable ASCII characters.
D2,aaa...aX	Display characters "aaa" and save message in non-volatile memory.

Default

Upon power-up, or after receiving a DCL, SDC, or J0X command, the message stored with the D2 command remains saved in memory.

Description

The D command lets you display messages on the front panel. Up to 18 characters, including blanks, can be sent by simply following the appropriate D command with ASCII characters. Characters that can be displayed include: 0-9, A-Z (except X), arithmetic and most punctuation symbols.

If a character cannot be displayed, for example { or } (curly braces), no segments of that particular character will turn on.

Programming Notes

1. As with other device-dependent commands, the D command string must be terminated with an X.
2. Spaces in the command string are displayed.
3. Any extra characters in the string are ignored. If there are fewer than 18 characters between the comma and the X, the characters are left-justified and the rest of the display is blank.
4. Error messages overwrite a displayed user message.
5. To return the display to normal, send D0X, perform device clear, or return the Model 236/237/238 to the local state.
6. The U2 command is used to get the stored message. This is shown in the program example that follows.

Programming Example

```
10    DIM Message$[25]                 ! Dimension string for message
20    REMOTE 716                       ! Set unit for IEEE-488 communi-
                                         cation
```

```
30    OUTPUT 716;"D2, CALIBRATED     ! Send message
      6-7-89X"
40    OUTPUT 716;"U2X"               ! Request message that is stored
50    ENTER 716;Message$             ! Get data from unit
60    PRINT Message$                 ! Display message on controller
70    WAIT 3                         ! Wait 3 seconds
80    OUTPUT 716;"D0X"               ! Return display to normal
90    END
```

3.6.5 F – Source and Function

Purpose To program a source (V or I) and a function (dc or sweep).

Format **F(source),(function)**

Parameters

F0,0	Source voltage (and measure current)	dc
F0,1	Source voltage (and measure current)	Sweep
F1,0	Source current (and measure voltage)	dc
F1,1	Source current (and measure voltage)	Sweep

Default Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the dc function and the last progammed selection for source. A J0X command restores factory default settings of F0,0 (source V, dc function).

Description The F command selects the source and function. When programmed to source V, the instrument measures I and, conversely, when programmed to source I, the instrument measures V.

When programmed for dc, the instrument functions as a constant dc source. Dc function parameters are programmed with the B command (see paragraph 3.6.2). When programmed for sweeping, the instrument, when triggered, outputs a programmed sweep (see paragraph 3.6.15).

Programming Notes

1. Any time the F command is executed, the Model 236/237/238 is placed in an untriggered state.
2. Any time the "source" parameter value is changed, the instrument is placed in standby.
3. Each source (V and I) will remember its own unique setup configuration. Components that are remembered include:
   - A. Source value and range
   - B. Compliance value and measurement range
   - C. Integration time
   - D. Filter
   - E. Autorange
   - F. Dc delay
   - G. Default delay
   - H. Output sense
   - I. Sweep (Q) parameters

Programming Example

```
10    OUTPUT 716; "F0,1X"                ! Program to source V, sweep
20    OUTPUT 716; "F,0X"                 ! Change to dc function.
```

3.6.6 G — Output Data Format

Purpose

To select the type, format, and quantity of output data transmitted over the bus.

Format

G(items),(format),(lines)

Parameters

items — Sum of items in IEEE output string:

0 = No items
1 = Source value
2 = Delay value
4 = Measure value
8 = Time value

format — Format of IEEE output string:

0 = ASCII data with prefix and suffix
1 = ASCII data with prefix, no suffix
2 = ASCII data, no prefix or suffix
3 = HP binary data
4 = IBM binary data

lines — Number of lines per output:

0 = One line of dc data per talk
1 = One line of sweep data per talk
2 = All lines of sweep data per talk

Default

Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to G1,0,0 (dc source values in ASCII format with prefix and suffix).

Description

Whenever the instrument is addressed to talk, it sends one or more lines of its output data over the IEEE-488 bus to the controller. The format of output data is determined by how it is configured with the G command. Figure 3-3 shows an example of an ASCII output data string that includes all items, and is formatted for both prefix and suffix. Figure 3-4 shows the binary formats for all items selected.

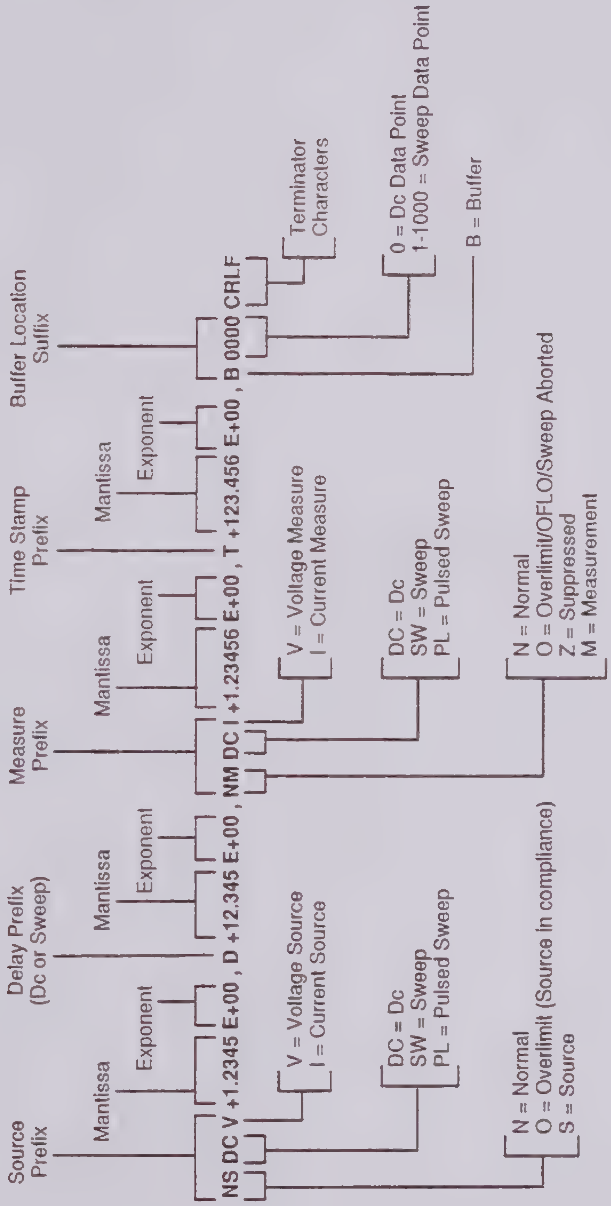

Source Prefix
Mantissa
Exponent
Delay Prefix (Dc or Sweep)
Mantissa
Exponent
Measure Prefix
Mantissa
Exponent
Time Stamp Prefix
Mantissa
Exponent
Buffer Location Suffix
NS DC V +1.2345 E+00 , D +12.345 E+00 , NM DC I +1.23456 E+00 , T +123.456 E+00 , B 0000 CRLF
V = Voltage Source
I = Current Source
DC = Dc
SW = Sweep
PL = Pulsed Sweep
N = Normal
O = Overlimit (Source in compliance)
S = Source
V = Voltage Measure
I = Current Measure
DC = Dc
SW = Sweep
PL = Pulsed Sweep
N = Normal
O = Overlimit/OFLO/Sweep Aborted
Z = Suppressed
M = Measurement
Terminator Characters
0 = Dc Data Point
1-1000 = Sweep Data Point
B = Buffer

Figure 3-3. *ASCII Data Format (G15,0,0)*

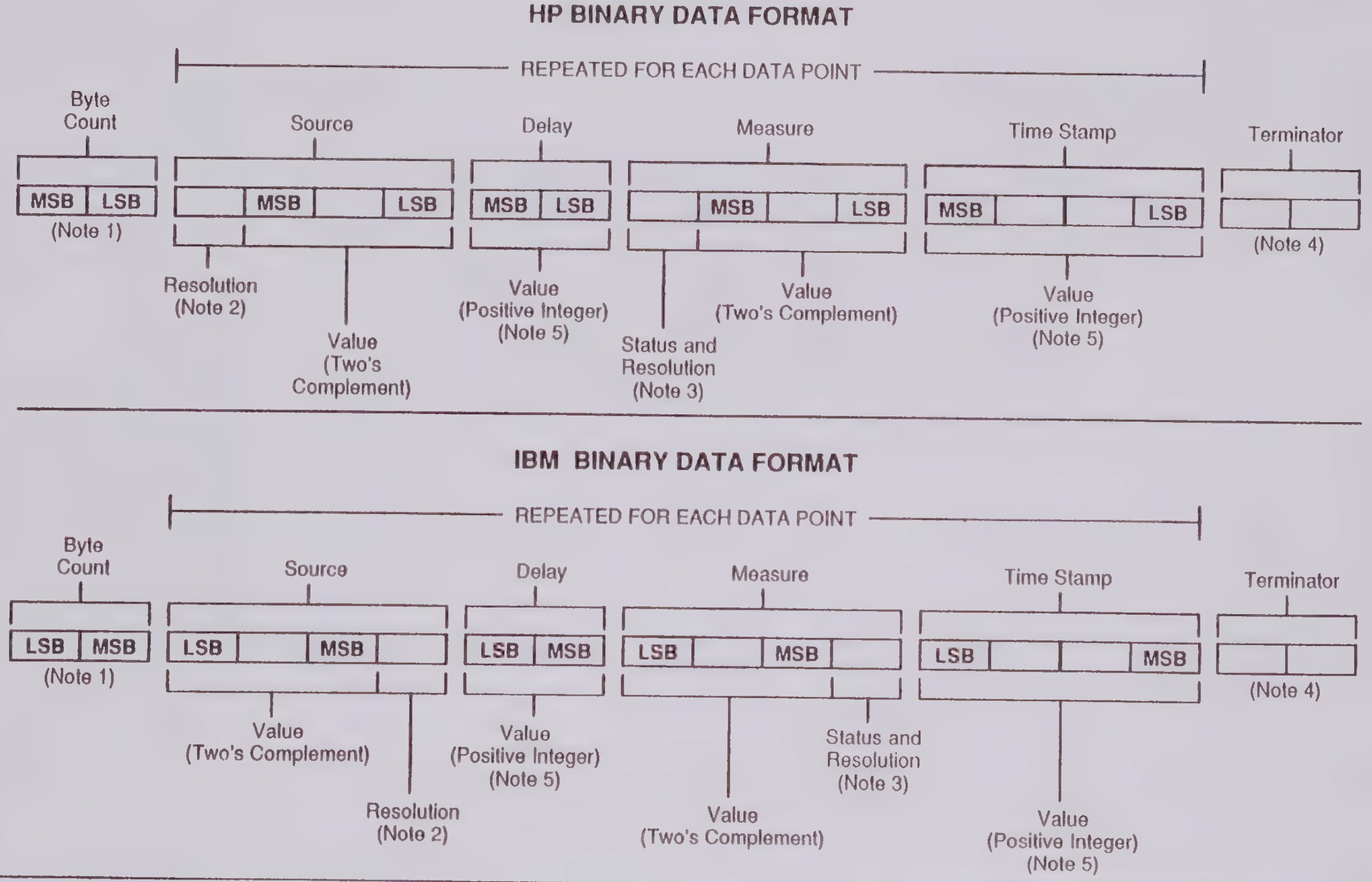

HP BINARY DATA FORMAT
REPEATED FOR EACH DATA POINT
Byte Count
MSB
LSB
(Note 1)
Source
MSB
LSB
Resolution (Note 2)
Value (Two's Complement)
Delay
MSB
LSB
Value (Positive Integer) (Note 5)
Measure
MSB
LSB
Status and Resolution (Note 3)
Value (Two's Complement)
Time Stamp
MSB
LSB
Value (Positive Integer) (Note 5)
Terminator
(Note 4)
IBM BINARY DATA FORMAT
REPEATED FOR EACH DATA POINT
Byte Count
LSB
MSB
(Note 1)
Source
LSB
MSB
Value (Two's Complement)
Resolution (Note 2)
Delay
LSB
MSB
Value (Positive Integer) (Note 5)
Measure
LSB
MSB
Value (Two's Complement)
Status and Resolution (Note 3)
Time Stamp
LSB
MSB
Value (Positive Integer) (Note 5)
Terminator
(Note 4)

Figure 3-4. Binary Data Format (G15,3,0 and G15,4,0)

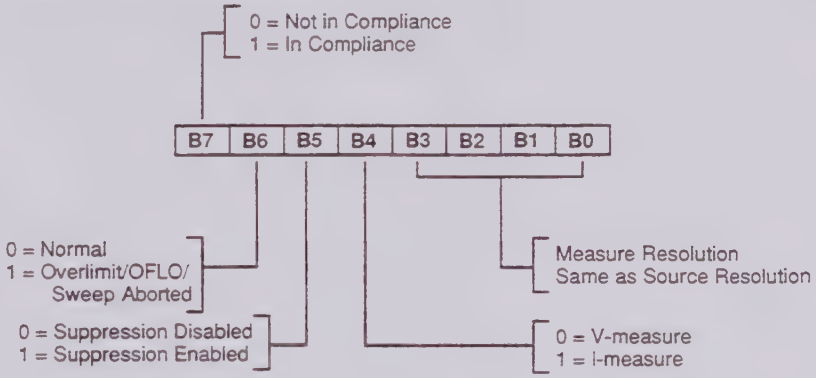
NOTES:

1. The byte count is the total number of bytes not including terminators.

2. Source Resolution:

0 =	E–14 amps	E–5 volts
1 =	E–13 amps	E–4 volts
2 =	E–12 amps	E–3 volts
3 =	E–11 amps	E–2 volts
4 =	E–10 amps	E–1 volts
5 =	E–9 amps	
6 =	E–8 amps	
7 =	E–7 amps	
8 =	E–6 amps	
9 =	E–5 amps	
10 =	E–4 amps	

3. Measure Status and Resolution:


0 = Not in Compliance
1 = In Compliance
B7
B6
B5
B4
B3
B2
B1
B0
0 = Normal
1 = Overlimit/OFLO/ Sweep Aborted
Measure Resolution
Same as Source Resolution
0 = Suppression Disabled
1 = Suppression Enabled
0 = V-measure
1 = I-measure

4. Terminator characters are selected with the Y command. They should not be used to terminate a binary transfer

5. Expressed as integer milliseconds.

Binary Data Format (G15,3,0 and G15,4,0) (Cont.)

Items

The "items" parameter selects which items to include in the IEEE output string. The items include the source value, the dc or sweep delay time, the measurement, and the time stamp. The parameter value is determined by adding the decimal values of the individual items that you want to include in the data string. Examples:

1. To include only the source value in the string, send G1,(format),(lines)X. (Enter values for "format" and "lines".)
2. To include both the source (G1) and measure (G4) values, send G5,(format),(lines)X.
3. To include all the items in the string, send G15,(format),(lines)X.

The source value in the string represents the programmed, not the actual source value. The time stamp value is referenced from the time a sweep is triggered.

Format

The "format" parameter selects how the data is sent. A parameter value of 0 programs the instrument to send ASCII data that contains both prefix and suffix. Prefixes are used to define each of the item values. The suffix indicates the buffer location where the data is stored. A parameter value of 1 sends ASCII data with prefix and without suffix, while a parameter value of 2 sends ASCII data without prefix or suffix.

Parameter values of 3 and 4 choose binary data in HP and IBM formats. If all lines of sweep data are selected with the "lines" parameter, the items between the byte count and terminators are repeated for each sweep point.

Lines

The "lines" parameter selects the number of data lines sent per talk. This data can be from the dc buffer (one line at a time) or the sweep buffer (one or all lines at a time). Each time you request all lines of sweep data, the entire buffer is sent from the beginning.

If a sweep is in progress and a measurement or time value is unavailable, the bus is held until it becomes available. If a sweep has aborted or is not in progress, measurement and time values are sent if available, or a value of zero is sent if not available. In addition, an aborted sweep is indicated in the ASCII measure prefix and binary measure status.

Obtaining Data

Generally, data is placed into a string or numeric variable. For example, a typical input sequence for an HP controller with BASIC 4.0 is:

```
ENTER 716;Measure$
```

In this instance, the complete measure string is placed in the Measure$ variable. In cases where numeric input is required, the instrument can be programmed in format 2 to eliminate the prefix and suffix, and a single measurement can be placed directly into a numeric variable as shown below:

```
ENTER 716;Measure
```

Source and Measure Status Conditions

Both the ASCII and binary formats include status flags for the source and measure values. These are shown in Figure 3-3 and Figure 3-4 and described below:

- An "overlimit" or "in compliance" in ASCII or binary format occurs when the measured value reaches the compliance level. The source value that is returned represents the programmed value, not the actual value. The measured value that is returned represents an actual measurement taken at the compliance level.
- A "suppressed measurement" in ASCII format is flagged when suppression has been enabled with the Z1 command. (See paragraph 3.6.24.) The value that is returned is the difference between the actual and suppressed readings.

Programming Notes

1. With either binary transfer mode, the controller or program should be set up to terminate on the byte count or detection of EOI.
2. Table 3-7 lists the number of bytes that are transmitted for the various data formats.
3. As the data is transmitted in continuous strings, without carriage returns or line feeds between buffer locations, you must format the data for display or printing legibility (shown in the example program).
4. A time value of zero is output with dc data.
5. Sweep data can be requested as soon as the sweep is triggered. The data will be sent as it becomes available. Using this method to obtain data, rather than waiting for sweep done, decreases throughput time.
6. If only partial sweep data is obtained with one line per talk, the G command should be sent to reset the buffer pointer to the first line, even if a new sweep has been triggered.
7. Only terminator characters are sent if sweep data is requested while in dc, or dc data is requested while in sweep.
8. Dc measurements are output only once per source-delay-measure cycle. If output requests are faster than the reading update rate, the bus is held off until the reading is available.
9. A measurement overflow is indicated at 112.5% of full scale range.

Programming Example

```
10   DIM Source$[200]              ! Dimension string for source val-
                                     ues
20   REMOTE 716                    ! Set for IEEE-488 communication
30   OUTPUT 716;"F0,1X"            ! Source V, measure I, sweep func-
                                     tion
40   OUTPUT 716;"Q1,0,5,1,2,0X"    ! Linear stair sweep, six 1V steps,
                                     11V or 15V range, no delay
50   OUTPUT 716;"G1,0,2X"          ! Request source data in ASCII
                                     with prefix and suffix
60   ENTER 716;Source$             ! Get data from unit
70   PRINT Source$[1,22]           ! Print source data
80   PRINT Source$[24,45]
```

```
 90     PRINT Source$[47,68]
100     PRINT Source$[70,91]
110     PRINT Source$[93,114]
120     PRINT Source$[116,137]
130     END
```

Table 3-7. Byte Counts for Data Items and Formats (One Line of dc or Sweep Data per Talk)

Items	0 Prefix and Suffix	1 Prefix, No Suffix	2 No Prefix or Suffix	3 HP Binary	4 IBM Binary
0 None	5	0	0	2	2
1 Source	22	16	11	6	6
2 Delay	18	12	11	4	4
4 Measure	23	17	12	6	6
8 Time	19	13	12	6	6
15 All	67	61	49	16	16

Notes:

1. Terminator characters, which are selected with the Y command, add 0, 1, or 2 bytes to the count.
2. When more than one item is selected, commas are sent to separate the items.
3. When all lines of sweep data per talk are selected, commas are sent to separate the lines.

3.6.7 H — IEEE Immediate Trigger

Purpose

To provide an immediate trigger stimulus from the IEEE-488 bus.

Format

H0X

Description

The H command immediately triggers the instrument. The instrument responds to this trigger regardless of what trigger origin is programmed by the T command (see paragraph 3.6.18).

Programming Notes

1. This command is most useful when an external trigger origin is used (e.g., cross-triggered units) and a software trigger is desired to start the operation.
2. Each H0 command must be sent with an X immediately following it (i.e., N1H0X, not H0N1X).

Programming Example

```
10    REMOTE 716
20    OUTPUT 716;"F0,0X"          ! Source V, measure I, dc
30    OUTPUT 716;"B1,1,0X"        ! Set 1V bias on 1.1V or 1.5V range
40    OUTPUT 716;"R1X"            ! Enable triggers
50    OUTPUT 716;"N1X"            ! Turn on output
60    OUTPUT 716;"H0X"            ! Immediate trigger over bus
70    OUTPUT 716;"N0X"            ! Turn off output
80    END
```

3.6.8 J — Self-tests

Purpose

To restore factory defaults and test memory and front panel display.

Format

JnX

Parameters

J0X	Restore factory defaults
J1X	Perform memory test
J2X	Perform display test

Description

The J0X command starts execution of the complete power-up initialization and restores parameter values to their factory defaults. (See Table 3-4 for power-up and factory default values.)

The J1X command performs the memory test portions of the power-up sequence. For example, if the checksum test of the calibration constants fails, the message IOU CAL CHECKSUM is displayed. The J2X display test momentarily lights all segments of the display for your inspection.

Programming Notes

1. Allow approximately three seconds for the instrument to complete the factory default test. All other tests are shorter.
2. The instrument holds off bus operation with the NRFD line during self-test operation. Thus, no commands can be sent during the self-test if hold-off on X is enabled.
3. Examine the error status word with the U1 command to determine what failures occurred. This is shown in the programming example.
4. Each J command must be sent with a X immediately following the numerical parameter (i.e., J0X).

Programming Example

```
10   DIM Error$[50]            ! Dimension for error status
20   REMOTE 716                !
30   OUTPUT 716;"J1X"          ! Perform memory test
40   WAIT 2                    ! Wait for test execution
50   OUTPUT 716;"U1X"          ! Request error status word
60   ENTER 716;Error$          ! Get error status
70   PRINT Error$              ! Print error status
80   END
```

3.6.9 K — EOI and Bus Hold-Off

Purpose To enable/disable EOI and bus hold-off on X.

Format **Kn**

Parameters

K0	Enable EOI	Enable bus hold-off on X
K1	Disable EOI	Enable bus hold-off on X
K2	Enable EOI	Disable bus hold-off on X
K3	Disable EOI	Disable bus hold-off on X

Default Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to K0 (both EOI and bus hold-off on X enabled).

Description The EOI line provides one method to positively identify the last byte in the data string sent by the instrument. When enabled, EOI is asserted with the last byte the instrument sends over the bus.

Bus hold-off allows the instrument to temporarily hold up bus operation via the NRFD line when it receives the X character until all commands are processed. Hold-off will ensure that all commands have been executed at the time the bus is released. Typical hold-off times are discussed in paragraph 3.7.

Programming Notes

1. Some controllers rely on EOI to terminate their input sequences. Suppressing EOI may cause the controller sequence to hang.
2. When reading the entire sweep buffer, EOI is asserted only at the end of the transmission.
3. When enabled, EOI is asserted with the last byte in the terminator (if enabled), or with the last byte in the data string if the terminator has been disabled.
4. When bus hold-off is enabled, all bus activity is held up for the duration of the hold-off period — not just the activity associated with the Model 236/237/238.

Programming Example

```
10   OUTPUT 716; "K1X"          ! No EOI, hold-off on X
20   OUTPUT 716; "K2X"          ! Send EOI with last byte, do not
                                  hold-off on X
```

3.6.10 L — Compliance

Purpose

To program the compliance value and compliance/measurement range.

Format

L(level),(range)

Parameters

level — Specifies the compliance level (I or V):

I-measure	(236/237)	−100.00 to +100.00mA
	(238)	−1.0000 to +1.0000A
V-measure	(236/238)	−110.00 to +110.00V
	(237)	−1100.0 to +1100.0V

range — Selects the compliance/measurement range:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option.

Default

Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selections. A J0X command sets the instrument to a compliance level of 10mA/10V on a range of 10mA/11V or 15V.

Description

The L command sets the compliance level for the programmed source and selects the measurement range. If the unit is programmed to source current, then the L command sets a voltage compliance and selects a voltage measurement range. Conversely, if the unit is programmed to source voltage, the L command sets a current compliance and selects a current measurement range.

Programming Notes

1. When a fixed range is specified, compliance range and measurement range are the same.
2. With autorange selected, the programmed compliance value will be adjusted to the highest on-scale range and the measure range will be adjusted to the highest on-scale measurement.
3. In sweep operation, a change in compliance occurs immediately; in dc operation, a change must be triggered to go into effect.
4. The U5 compliance value word indicates the voltage or current compliance value

presently in effect. (See paragraph 3.6.19.)

5. Error and warning conditions for the L command are described in the U1 error status word and U9 warning status word (see paragraph 3.6.19).
6. To maintain the specified t_{ON} and t_{OFF} of pulsed sweeps, the delay times are recalculated for changes in the current compliance range that affect the default delay (if enabled).
7. Triggering a pulsed sweep with autorange enabled can affect the resulting t_{ON} and t_{OFF} because a measure autorange change will extend the measure phase of the S-D-M cycle.
8. The compliance value is interpreted as an absolute value.
9. A minimum compliance value of ±100 counts is maintained internally (e.g., if "L0E–3,9X" was programmed, a compliance value of ±1mA would be used).
10. The bus hold-off times for a change in compliance includes any dc or sweep delay.

Programming Example

```
10   OUTPUT 716; "F0,0X"          ! Source V, measure I, dc
20   OUTPUT 716; "B1,1,0X"        ! Source 1V on the 1.1V 1.5V range.
30   OUTPUT 716; "L500E–6,7X"     ! Set 500µA compliance current
                                    and 1mA measurement range.
40   OUTPUT 716; "H0X"            ! Trigger
```

3.6.11 M — SRQ Mask and Serial Poll Byte Format

Purpose To program which conditions generate an SRQ (service request).

Format **M(mask),(compliance)**

Parameters *mask* — Sum of the binary bits in the SRQ mask:

0 = SRQ disabled
1 = Warning
2 = Sweep Done
4 = Trigger Out
8 = Reading Done
16 = Ready for Trigger
32 = Error
128 = Compliance

compliance — Allowable times to detect SRQ on compliance:

0 = SRQ on compliance when it occurs during a delay or measure phase or idle time.

1 = SRQ on compliance when it occurs in the measure phase only.

Default Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to M0,0 (SRQ is disabled, compliance during delay, measure, or idle).

Description The SRQ command selects which conditions cause the Model 236/237/238 to generate an SRQ (service request). Once an SRQ is generated, the serial poll byte can be checked to determine if the Model 236/237/238 was the instrument that generated the SRQ and, if so, what conditions caused it.

An 8-bit SRQ mask determines which conditions cause an SRQ to be generated. (See Figure 3-5.) By sending the appropriate M command, you can set the bit or bits to enable SRQ generation if those particular conditions occur.

Possible conditions include:

- Warning (M1,) — A warning condition has occurred.
- Sweep Done (M2,) — All data taken is available for reading.
- Trigger Out (M4,) — Each trigger out, including an end of sweep trigger out, generates an SRQ.
- Reading Done (M8,) — Measurement and processing of data is complete.
- Ready for Trigger (M16,) — The unit is ready for a trigger.
- Error (M32,) — An error condition has occurred.
- Compliance (M128,) — Compliance occurred during delay or measure phase or idle time, or measurement phase only.

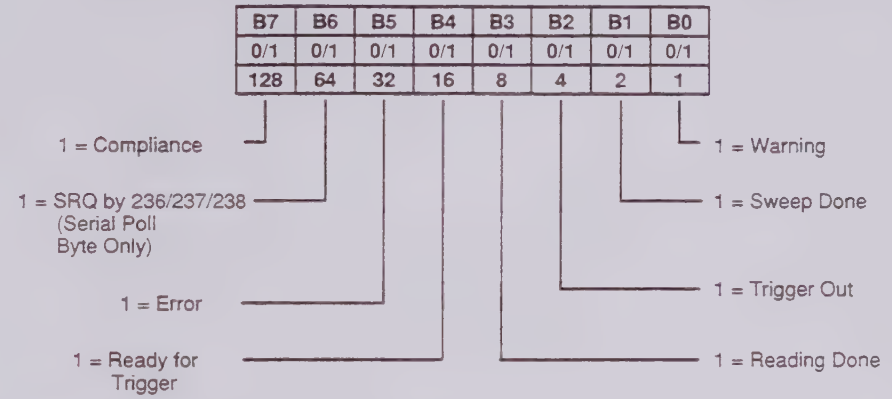


Figure 3-5. SRQ Mask and Serial Poll Byte Format

Serial Poll Byte

The general format of the serial poll byte is shown in Figure 3-5. Note that all bits except for bit 6 correspond to the bits in the SRQ mask. These bits flag the following conditions:

Bit 0 (Warning) — Set when one of the following warnings has occurred:

- The unit is uncalibrated.
- Calibration mode entered with CAL LOCK switch in LOCKED position.
- Programmed value is out of range (greater than that allowed by range, or step value is less than range resolution).
- The sweep buffer has been filled with source and delay values.
- Attempted to append or modify a non-existing sweep.
- Specified pulse times cannot be met.
- The instrument was programmed when not in remote.
- Programmed source and compliance ranges are 1.1kV and 100mA (237), or 110V and 1A (238).
- A measurement overflow has occurred, or a sweep has aborted.
- Unit triggered while processing a previous command.

This bit is cleared when the U9 status word is read to determine the type of warning (see paragraph 3.6.19).

Bit 1 (Sweep Done) — Set when a sweep has completed. Cleared when a new sweep is triggered, a sweep is appended, or a new sweep is created.

Bit 2 (Trigger Out) — Set when the unit sends a trigger out pulse, including at the end of a sweep. Cleared on serial poll with SRQ asserted, reprogramming of source/measure controller (i.e., with an A, B, C, F, J, L, N, O, P, Q, S, T, V, W command), or execution of the M command.

Bit 3 (Reading Done) — Set when a measurement has completed. Cleared on reprogramming of source/measure controller (i.e., with an A, B, C, F, J, L, N, O, P, Q, S, T, V, W command), or a read of measurement over the bus.

Bit 4 (Ready for Trigger) — Set when the instrument is ready for a trigger. Cleared when unit executes bus or front panel changes, or in calibration mode. Disabling triggers with the R0 command also clears the Ready for Trigger bit. It remains cleared until triggers are enabled and the instrument is ready for a trigger.

Bit 5 (Error) — Set when one of the following errors has occurred:

- A trigger overrun error has occurred.
- An illegal device-dependent command (IDDC) or an illegal device-dependent command option (IDDCO) was transmitted.
- An interlock condition exists.
- An illegal measure or source range was programmed.
- An invalid mix of sweep types was attempted.
- An attempted log sweep passes through zero.
- A non–calibration command was programmed while in cal mode, or a calibration command was programmed while not in cal mode, or a Model 237/238 cal command was sent to a Model 236.
- A self–test or power–up test has failed.
- A calibration error has occurred.
- Source autoranging in pulse sweep was attempted.

This bit is cleared when the U1 status word is read to determine the type of error (see paragraph 3.6.19).

Bit 6 (RQS, Request for Service) — Set if the unit has asserted SRQ. Cleared when the instrument is serial polled.

Bit 7 (Compliance) — Set when compliance is reached during the delay or measure phases, or idle time (M,0X), or when compliance is reached during the measure phase only (M,1X). Cleared on serial poll (if SRQ on compliance asserted), reprogramming of source/measure controller (i.e., with an A, B, C, F, J, L, N, O, P, Q, S, T, V, W command), or execution of the M command.

Programming Notes

SRQ Mask

1. The instrument may be programmed to generate an SRQ for more than one set of conditions simultaneously. To do so, simply add up the decimal bit values for the required SRQ conditions. For example, to enable SRQ under sweep done (M2) and trigger out (M4), send M6,X.
2. Send M0,X to disable SRQ. This command clears all bits in the SRQ mask.

Serial Poll Byte

1. Even with SRQ disabled, the serial poll byte can be read to determine instrument conditions. All set bits remain latched until power is cycled, a DCL, SDC, or J0X is sent, or the specified clear bit condition is met.
2. The serial poll byte should be read to clear the SRQ line once the instrument has generated an SRQ. All bits in the serial poll byte are latched when the SRQ is generated. Bit 6 (SRQ) is cleared when the serial poll byte is read.
3. If an error or warning occurs, bit 5 (error) or bit 0 (warning) in the serial poll byte

latches and remains so until the U1 error status word or U9 warning status word is read. These status words define the nature of the error or warning.

Programming Example

```
 10   DIM Error$[50]                     ! Dimension string for error
 20   REMOTE 716
 30   OUTPUT 716;“M32,0X”                ! Program for SRQ on error
 40   OUTPUT 716;“H1X”                   ! Program illegal option
 50   S=SPOLL (716)                      ! Serial poll the 236/237/238
 60   IF NOT BIT(S,5) THEN 50            ! Wait for SRQ to occur
 70   PRINT “B7 B6 B5 B4 B3 B2 B1 B0”    ! Label the bit positions
 80   FOR I=7 TO 0 STEP –1               ! Loop eight times
 90   PRINT BIT(S,I);                    ! Print the bit positions
100   NEXT I
110   PRINT
120   OUTPUT 716;“U1X”
130   ENTER 716;Error$
140   PRINT Error$
150   END
```

3.6.12 N — Operate

Purpose

To place the instrument in operate or standby mode.

Format

Nn

Parameters

N0	Standby
N1	Operate

Default

Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to N0 (standby).

Description

In operate, the programmed bias level is available at the output of the instrument. When programmed for sweep operation, the bias level is output, but the sweep does not start until a trigger is received.

In standby, the programmed bias level is removed from the output. If in the middle of a sweep, the sweep is, of course, terminated if the unit goes to standby. The source measure unit will output 0V on the 1.1V (Model 236/237) or 1.5V (Model 238) range whether in Source V Measure I or Source I Measure V. Refer to paragraph 2.14 for a complete definition of standby, which also describes standby current compliance values.

Programming Notes

1. The instrument goes to standby when the F command (source and function) changes the source.
2. Error conditions for the N command are described in the U1 error status word (see paragraph 3.6.19).
3. If the interlock cable has been detected, no interlock condition must be present for the instrument to go into operate. While the unit is in operate, if an interlock condition becomes present, the unit will go into standby.
4. In standby mode, the instrument is set internally to local sense. For applications where guard is switched, program the unit to local sense before the switch occurs to allow for safe switching.

Programming Example

```
10    OUTPUT 716;"R1X"          ! Enable triggers
20    OUTPUT 716;"N1X"          ! Place instrument in operate
30    OUTPUT 716;"H0X"          ! Immediate bus trigger

10    OUTPUT 716;"N0X"          ! Place instrument in standby
```

3.6.13 O — Output Sense

Purpose To select local or remote output sensing.

Format **On**

Parameters

O0	Local sense for V-source feedback and measurement
O1	Remote sense for V-source feedback and measurement

Default Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to O0 (local sense).

Description The O command selects local or remote sensing. Local sensing is performed at the output connections of the Source Measure Unit; remote sensing is performed at the load by external sense leads.

WARNING

You must connect the sense leads before programming remote sensing. Failure to do so causes a safety hazard with potentially lethal voltages at OUTPUT HI and it's GUARD, and the GUARD surrounding SENSE HI.

When sourcing voltage and measuring current with remote sensing, the sense leads provide a feedback voltage. If the feedback voltage is less than the programmed voltage, the internal voltage source is increased until the voltages are equal. Remote sensing compensates for test lead I/R drops, ensuring that the programmed voltage level is delivered to the load.

When sourcing current and measuring voltage with remote sensing, the voltage reading is the actual voltage drop across the load. Test lead I/R drops are not included in the reading.

As a general rule, remote sensing should be used when source and/or measurement levels may develop significant I/R drops.

Programming Notes In standby mode, the instrument is set internally to local sense. For applications where guard is switched, program the unit to local sense before the switch occurs to allow for safe switching.

Programming Example

```
10    OUTPUT 716; "O1X"               ! Select remote sensing.
20    OUTPUT 716; "O0X"               ! Select local sensing.
```

3.6.14 P — Filter

Purpose

To control the number of readings averaged.

Format

Pn

Parameters

P0	Filter disabled
P1	2 readings
P2	4 readings
P3	8 readings
P4	16 readings
P5	32 readings

Default

Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selection. A J0X command sets the instrument to P0 (filter disabled).

Description

The P command controls the amount of filtering for each measurement. With the filter enabled, the unit acquires and averages up to 32 successive A/D conversions for each measurement. Since noise is mostly random in nature, it can be largely canceled out with this method. With the filter disabled, only one reading is taken.

Programming Notes

1. Filtering only occurs on a measurement, not across measurements.
2. Filtering can have significant impact on measurement speed and allowable pulse times.
3. If a pulsed sweep is in the buffer, changing the filter selection causes the instrument to recalculate the delay times to maintain the specified t_{ON} and t_{OFF}.
4. The conversions averaged are per the selected integration time.

Programming Example

```
10    OUTPUT 716; "P3X"        ! Enable filter and set to eight
                                 readings.
20    OUTPUT 716; "P0X"        ! Disable filter.
```

3.6.15 Q — Create/Append Sweep List

Purpose To program sweep operation parameters in a new list or append a current list.

Format **Qwaveform,(param1),(param2),...**

Where:

waveform = Sweep waveform type
param = Sweep parameter

Parameters Create sweep list:

Q0,(level),(range),(delay),(count)	Fixed Level
Q1,(start),(stop),(step),(range),(delay)	Linear Stair
Q2,(start),(stop),(points),(range),(delay)	Logarithmic Stair
Q3,(level),(range),(pulses),(t_{ON}),(t_{OFF})	Fixed Level Pulsed
Q4,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})	Linear Stair Pulsed
Q5,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})	Logarithmic Stair Pulsed

Append sweep list:

Q6,(level),(range),(delay),(count)	Fixed Level
Q7,(start),(stop),(step),(range),(delay)	Linear Stair
Q8,(start),(stop),(points),(range),(delay)	Logarithmic Stair
Q9,(level),(range),(pulses),(t_{ON}),(t_{OFF})	Fixed Level Pulsed
Q10,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})	Linear Stair Pulsed
Q11,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})	Logarithmic Stair Pulsed

count — Number of source-delay-measure cycles in a single sweep (1 to 1000)

delay — Sweep delay in milliseconds (0 to 65000)

level — Specifies the output level of a fixed level or fixed level pulse sweep (I or V):

I-source	(236/237)	–100.00 to +100.00mA
	(238)	–1.0000 to +1.0000A
V-source	(236/238)	–110.00 to +110.00V
	(237)	–1100.0 to +1100.0V

points — Specifies the number of points per decade in a log stair or log stair pulsed sweep:

0 = 5 points per decade
1 = 10 points per decade
2 = 25 points per decade
3 = 50 points per decade

pulses — Quantity of pulses in a pulse sweep waveform (0-500)

range — Selects the source range in all sweep types:

	I-source	V-source
0 =	Auto	Auto
1 =	1nA	1.1V (236, 237); 1.5V (238)
2 =	10nA	11V (236, 237); 15V (238)
3 =	100nA	110V
4 =	1µA	1100V (237)
5 =	10µA	*
6 =	100µA	*
7 =	1mA	*
8 =	10mA	*
9 =	100mA	*
10 =	1A (238)	*

*Illegal V-source option.

start, stop — Starting and stopping source values for stair waveforms.

I-source (236, 237)	–100.00 to +100.00mA
(238)	–1.0000 to +1.0000A
V-source (236, 238)	–110.00 to +110.00V
(237)	–1100.0 to +1100.0V

step — Incremental absolute value for stair sweeps. Maximum value is twice the full scale range of the highest range used in generating the sweep.

I-source (236, 237)	–200.00 to +200.00mA
(238)	–2.0000 to +2.0000A
V-source (236, 238)	–220.00 to +220.00V
(237)	–2200.0 to +2200.0V

t_{ON} — Duration of sweep level in milliseconds (0-65000)

t_{OFF} — Duration of bias level in milliseconds (0-65000)

Default

Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selections. All items in the sweep buffer are preserved.

A J0X command restores factory default values of 1V/1mA for level/start, 10V/10mA for stop, 1V/1mA for step, 11V/10mA for range, 0msec for delay, 10 for count/pulses, 10 log points per decade, and 100msec for t_{ON}/t_{OFF}. All items in the sweep buffer are cleared.

Description

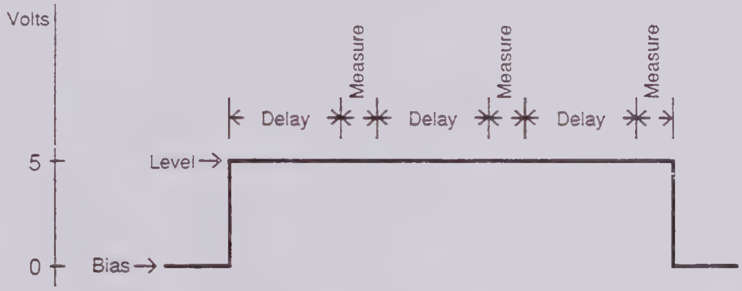
The Q command creates or appends a sweep list by defining the parameters of a selected sweep type. The sweep types include: fixed level, linear stair, logarithmic stair, fixed level pulsed, linear stair pulsed, and logarithmic stair pulsed.

For all sweeps, the last programmed bias value becomes the output level of the unit before and after the sweep. When a pulsed sweep waveform is created or appended, the last programmed bias value also becomes the output level during the t_{OFF} and idle times of the sweep. Therefore, the B command should precede or reside in the same command string as the Q command, but not in a separate command string after the Q command.

Once a sweep list is created, it is stored in battery backed-up memory for future use. However, one and only one sweep list can be saved. Creating a new sweep list destroys the old sweep list.

Fixed Level Sweep (Q0)

The Q0 command selects a fixed level (or constant) sweep. (See Figure 3-6.) The parameters for this command create a sweep at a specified source value of "level". The "count" parameter specifies the number of measurements to take and store in the sweep buffer. The "delay" parameter specifies the desired delay time before each measurement. An appropriate source "range" is also specified. Use a fixed level sweep instead of the dc function if you want time stamping of the measurements.



Sweep Point	Source Value	Sweep Delay
1	5V	100 msec
2	5V	100 msec
3	5V	100 msec

Q0, 5, 2, 100, 3

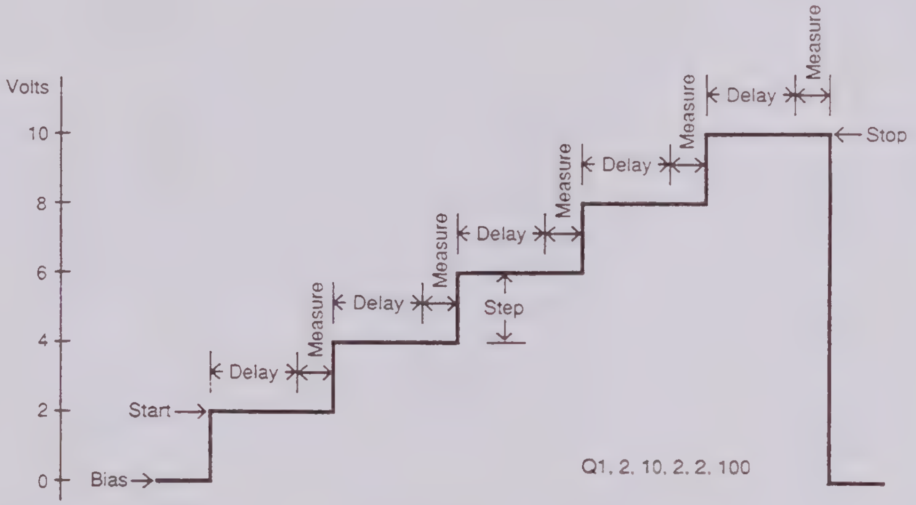
Figure 3-6. Fixed Level Sweep Waveform

Linear Stair Sweep (Q1)

The Q1 command selects a linear stair sweep. (See Figure 3-7.) The staircase starts at a specified source value of "start" and ends at the specified "stop" source value, inclusively. The "step" parameter specifies the increment of each staircase step and is interpreted as an absolute value, with the start and stop values determining the slope of the ramp. The larger of the start/stop values also determines the required resolution of the step (e.g., with a start of 10mA and a stop of 100mA, the step must be no less than 10μA or a step of 0 will be used, yielding a buffer filled with 10mA source values).

Source "range" can also be programmed. The specified sweep range determines the maximum start, stop, and step values. With autoranging, the start or stop value that determines the highest range will also govern the largest step size allowed. With either a fixed range or autorange, the maximum step value is twice the full scale range of the highest range used in generating the sweep. For example, the command Q1,–10,10,20,0,0 creates a 2-step sweep (–10V, 10V). The "delay" parameter determines the time before each measurement.

A linear stair sweep is shown in the first programming example.



Sweep Point	Source Value	Sweep Delay
1	2V	100 msec
2	4V	100 msec
3	6V	100 msec
4	8V	100 msec
5	10V	100 msec

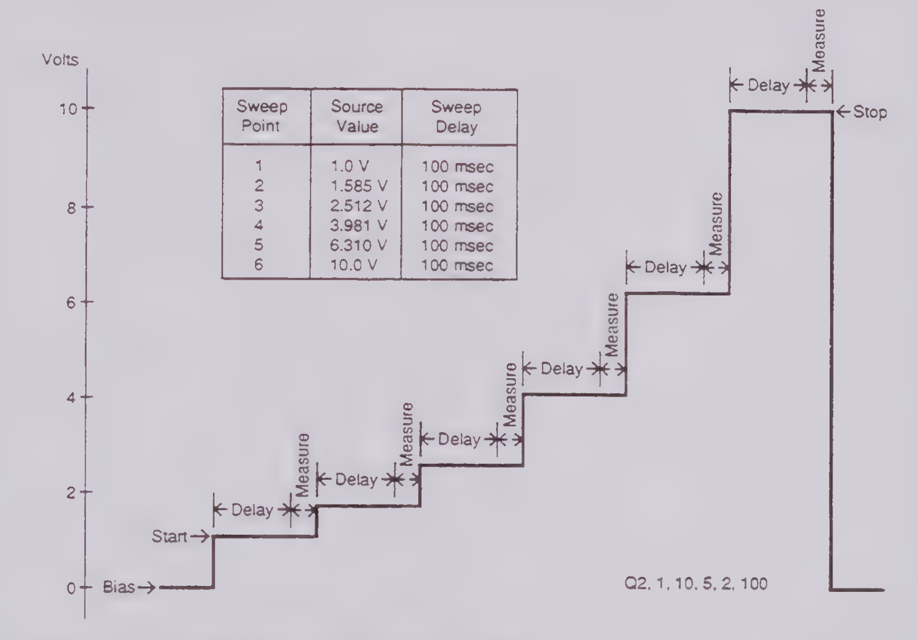
Figure 3-7. Linear Stair Sweep Waveform

Logarithmic Stair Sweep (Q2)

The Q2 command selects a logarithmic stair sweep. (See Figure 3-8.) The sweep starts at the specified source value "start" and ends at the "stop" source value. The "points" parameter specifies the number of log source/measure points per decade.

Log points are evenly spaced within the log scale of the decade. For example, a "points" parameter of 0 specifies that there will be five source/measure points within each decade that the source encompasses. If the sweep range is from 1V to 100V, then the five points in the first decade (1V to 10V) would be at approximately 1V, 1.585V, 2.512V, 3.981V and 6.310V. The five points in the second decade (10V to 100V) would be at approximately 10V, 15.85V, 25.12V, 39.81V and 63.10V. Log decades start at the specified beginning source value "start". The "stop" value is always included even if it does not fall in logarithmic progression. The slope of the ramp is determined by the start and stop values; the ramp is not allowed to pass through zero.

Source range is specified by the "range" parameter. The time period at each source/ measure point is largely determined by the specified "delay".



Sweep Point	Source Value	Sweep Delay
1	1.0 V	100 msec
2	1.585 V	100 msec
3	2.512 V	100 msec
4	3.981 V	100 msec
5	6.310 V	100 msec
6	10.0 V	100 msec

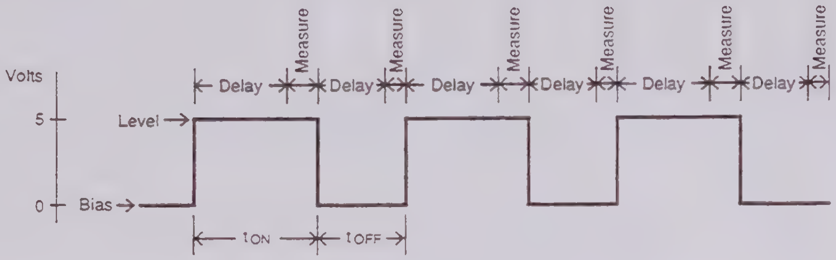
Figure 3-8. Logarithmic Stair Sweep Waveform

Fixed Level Pulsed Sweep (Q3)

The Q3 command selects a fixed level pulsed sweep. (See Figure 3-9.) Each pulse consists of two S-D-M cycles, one during the on-time and another during the off-time.

The pulse amplitude during the on-time is specified by the "level" parameter.During the pulse off-time, the pulse amplitude is the same as the bias level when the sweep was created. The source range is specified by the "range" parameter (autorange is not permitted). The quantity of pulses in the sweep is determined by the "pulse" parameter.

The on and off times are specified by t_{ON} and t_{OFF}, where t_{ON} is the duration of the sweep level and t_{OFF} is the duration of the bias level. From the values of t_{ON} and t_{OFF}, the instrument calculates sweep delays for the on and off-times. It takes into account other instrument operating parameters, such as integration time, that have an effect on the S-D-M width.



Sweep Point	Source Value	tON/tOFF
1	5V	100 msec
2	0V	70 msec
3	5V	100 msec
4	0V	70 msec
5	5V	100 msec
6	0V	70 msec

Q3, 5, 2, 3, 100, 70

Figure 3-9. Fixed Level Pulsed Sweep Waveform

Linear Stair Pulsed Sweep (Q4)

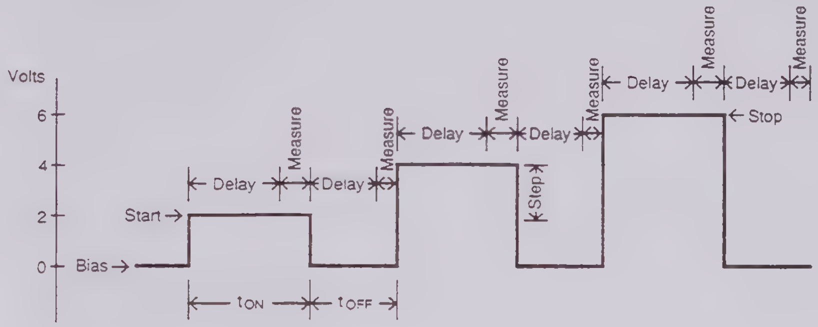
The Q4 command selects a linear stair pulsed sweep. (See Figure 3-10.) Each pulse consists of the two S-D-M cycles, one during the on-time ad another during the off-time.

The amplitude of the first pulse on-time is specified by the "start" parameter. The "stop" parameter determines the amplitude of the last pulse during the on-time. During the off-time, the pulse amplitude is the same as the bias level when the sweep was created.

The "step" parameter specifies the increment of each staircase and is interpreted as an absolute value, with the start and stop values determining the slope of the ramp. The larger of the start/stop values also determines the required resolution of the step (e.g., with a start of 10mA and a stop of 100mA, the step must be no less than 10μA or a step of 0 will be used, yielding a buffer filled with 10mA and bias source values).

As with all sweeps, the source range is specified by the "range" parameter (autorange is not permitted). The sweep range determines the maximum start, stop, and step values. The maximum step value is twice the full scale range of the specified range.

The on and off times are specified by t_{ON} and t_{OFF}, where t_{ON} is the duration of the sweep level and t_{OFF} is the duration of the bias level. From the values of t_{ON} and t_{OFF}, the instrument calculates sweep delays for the on and off-times. It takes into account other instrument operating parameters, such as integration time, that have an effect on the S-D-M width.



Q4, 2, 6, 2, 2, 100, 70

Sweep Point	Source Value	t_{ON}/t_{OFF}
1	2V	100 msec
2	0V	70 msec
3	4V	100 msec
4	0V	70 msec
5	6V	100 msec
6	0V	70 msec

Figure 3-10. Linear Stair Pulsed Sweep Waveform

A linear stair pulsed sweep is shown in the second programming example.

Logarithmic Stair Pulsed Sweep (Q5)

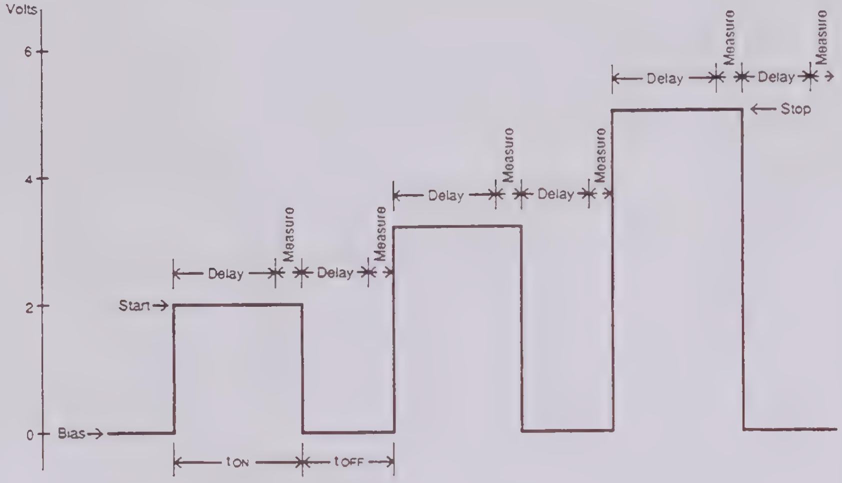
The Q5 command selects a logarithmic stair pulsed sweep. (See Figure 3-11.) This sweep is much like the linear stair pulsed sweep (Q4) excepts that it is performed logarithmically like the Q2 log stair sweep. Each pulse consists of two S-D-M cycles, one during the on-time and another during the off-time.

The amplitude of the first pulse on-time is specified by the "start" parameter. The "stop" parameter determines the amplitude of the last pulse during the on-time. During the off-time, the pulse amplitude is the same as the bias level when the sweep was created. The start and stop values determine the slope of the ramp.

The "points" parameter specifies the number of pulses per decade. The pulses are evenly spaced within the log scale of each decade that the source encompasses.

As with all sweeps, the source range is specified by the "range" parameter (autorange is not permitted).

The on and off times are specified by t_{ON} and t_{OFF}, where t_{ON} is the duration of the sweep level and t_{OFF} is the duration of the bias level. From the values of t_{ON} and t_{OFF}, the instrument calculates sweep delays for the on and off-times. It takes into account other instrument operating parameters, such as integration time, that have an effect on the S-D-M width.



Q5, 2, 5, 0, 2, 100, 70

Sweep	Source	tON /tOFF
1	2V	100 msec
2	0V	70 msec
3	3.17V	100 msec
4	0V	70 msec
5	5V	100 msec
6	0V	70 msec

Figure 3-11. Logarithmic Stair Pulsed Sweep Waveform

Appending Sweeps

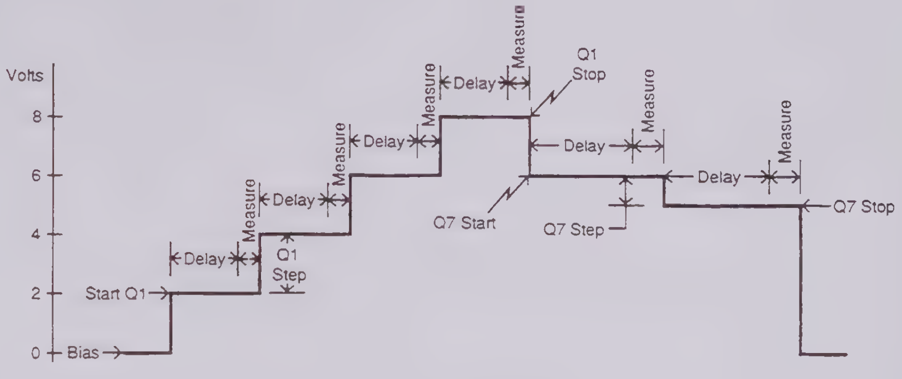
Q6 — Append fixed level sweep
Q7 — Append linear stair sweep
Q8 — Append logarithmic stair sweep
Q9 — Append fixed level pulsed sweep
Q10 — Append linear stair pulsed sweep
Q11 — Append logarithmic stair pulsed sweep

Existing sweeps can be appended with another sweep or sweeps until the buffer is filled. The only restriction is that you cannot mix non-pulsed sweeps with pulsed sweeps. For example, if a linear stair sweep is in the buffer, only a fixed level sweep, linear stair sweep, or log stair sweep can be appended to it, not a pulsed sweep.

Two linear stair pulsed sweeps are appended in the second programming example.

Programming Notes

1. If the bias and sweep ranges are not programmed to autorange, the same fixed range should be selected to prevent range changes during a sweep. Range changes affect sweep timing and, since the output level is momentarily set to zero during a range change, there could be an undesirable effect on the test in progress.
2. In autorange, the source range is adjusted for the highest on-scale sourcing possible.



Q1, 2, 8, 2, 2,100

Sweep Point	Source Value	Sweep Delay
1	2V	100 msec
2	4V	100 msec
3	6V	100 msec
4	8V	100 msec
5	6V	150 msec
6	5V	150 msec

Q7, 6, 5, 1, 2, 150

Figure 3-12. Creating and Appending Linear Stair Sweeps

3. If the source range is not specified, the instrument will try to place the source value on the present range. This could result in a VALUE OUT OF RANGE warning. Therefore, it is good practice to always specify source value and source range together.
4. Use the sweep delay to compensate for any settling time required by the external circuit connected to the source-measure unit.
5. Depending on your controller and program, a bus timeout may occur during a long sweep delay. If you trigger a reading and ask for it right away, the bus is held off until the measurement is available, possibly causing a timeout.
6. If the specified parameter values for t_{ON} and t_{OFF} are not long enough to account for measure autorange, filtering, integration time, and default delay, a warning is displayed (PULSE TIME NOT MET) and t_{ON} and t_{OFF} are extended as necessary.
7. Whenever measure autorange, filtering, integration time, and default delay are changed, the instrument recalculates the delays needed for pulsed sweeps. If you append a pulsed sweep with different t_{ON} and t_{OFF} times than the original waveform, subsequent delay calculations for the entire sweep will be based on the t_{ON} and t_{OFF} times of the appended waveform. Thus, it is good practice to set measure autorange, filtering, integration time, and default delay before appending pulsed sweeps.
8. An append waveform should be on the same range as the original to avoid a range change.
9. For easy data logging, set the bias equal to "level" of a fixed level pulsed sweep. Also, program t_{ON} equal to t_{OFF}. Then change the bias to the desired level. When the sweep is triggered, up to 1000 data points are logged at the t_{ON}/t_{OFF} interval.
10. If the start/stop values are less than the range resolution, the sweep is created using a value of zero. A step value less than the range resolution is a warning condition as the sweep buffer is filled with 1000 points of the start value.
11. A previously entered value for "level" becomes the default for the "start" value, and vice versa.

12. Only terminator characters are sent if sweep data is requested with the G command while the instrument is in the dc function (see paragraph 3.6.6).
13. Error and warning conditions for the Q command are described in the U1 error status word and U9 warning status word (see paragraph 3.6.19).

Programming Examples

```
 10   DIM Buffer$[200]                    ! Dimension sweep buffer string
 20   REMOTE 716                          !
 30   OUTPUT 716;“F0,1X”                  ! Source V, sweep
 40   OUTPUT 716;“B1,2,0X”                ! 1V bias, 11V or 15V range
 50   OUTPUT 716;“L2E–3,8X”               ! 2mA compliance, 10mA range
 60   OUTPUT 716;“Q1,1,10,1,2,0X”         ! Linear stair sweep, 1 to 10V, 1V
                                            steps, 11V or 15V range
 70   OUTPUT 716;“R1X”                    ! Enable triggers
 80   OUTPUT 716;“N1X”                    ! Go to operate
 90   OUTPUT 716;“H0X”                    ! Immediate bus trigger
100   OUTPUT 716;“G4,2,2X”                ! Set format for measure value,
                                            ASCII, all sweep data
110   ENTER 716;Buffer$                   ! Get sweep data
120   OUTPUT 716;“N0X”                    ! Go to standby
130   PRINT Buffer$                       ! Display sweep data
140   END
```

```
 10   DIM Buffer$[600]                    ! Dimension sweep buffer string
 20   REMOTE 716                          !
 30   OUTPUT 716;“F0,1X”                  ! Source V, sweep
 40   OUTPUT 716;“B1,2,0X”                ! 1V bias, 11V or 15V range
 50   OUTPUT 716;“L2E–3,8X”               ! 2mA compliance, 10mA range
 60   OUTPUT 716;“Q4,1,10,1,2,500,500X”   ! Linear stair pulsed sweep, 1 to
                                            10V, 11V or 15V range, 500msec
                                            on and off times
 70   OUTPUT 716;“Q10,10,1,1,2,500,500X”  ! Linear stair pulsed sweep, 10 to
                                            1V, 11V or 15V range, 500msec
 80   OUTPUT 716;“R1X”                    ! Enable triggers
 90   OUTPUT 716;“N1X”                    ! Go to operate
100   OUTPUT 716;“H0X”                    ! Immediate bus trigger
110   OUTPUT 716;“G4,2,2X”                ! Set format for measure value,
                                            ASCII, all sweep data
120   ENTER 716;Buffer$                   ! Get sweep data
130   OUTPUT 716;“N0X”                    ! Go to standby
140   PRINT Buffer$                       ! Display sweep data
150   END
```

3.6.16 R — Trigger Control

Purpose To enable/disable input and output triggers.

Format **Rn**

Parameter

R0	Disable input triggering and generation of output triggers
R1	Enable input triggering and generation of output triggers

Default Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to R1 (input and output triggers enabled).

Description With the R command you control whether the Model 236/237/238 responds to a trigger (from the TRIGGER IN jack, over the IEEE-488 bus, or a front panel key). The same command controls whether the instrument sends trigger signals via its TRIGGER OUT jack. The R0 command provides a way to easily disable triggers without having to change the trigger configuration. Execution of the R0 command also stops any presently triggered action.

Programming Notes When triggers are enabled, the MANUAL LED of the TRIGGER group flashes. An LED that is constantly on indicates that the unit is processing a trigger (except on power-up). After a source, function, or trigger configuration change (F or T command), the MANUAL LED goes from constant to flashing, and the unit needs another trigger to resume dc or sweep operations. Given the present states and actions performed, the next states of the the instrument are listed below (also see paragraph 3.6.18):

Present State	Action	Next State
Triggers disabled (MANUAL off)	R1X	Triggers enabled (MANUAL flashing)
Triggers enabled (MANUAL flashing)	R0X	Triggers disabled (MANUAL off)
	Trigger	Processing trigger (MANUAL constant)
Processing trigger (MANUAL constant)	F or T command	Triggers enabled (MANUAL flashing)
	R0X	Triggers disabled (MANUAL off)

Programming Examples

```
10    OUTPUT 716;"R0X"            ! Disable triggers
20    OUTPUT 716;"R1X"            ! Enable triggers
```

3.6.17 S — Integration Time

Purpose

To control the integration time and resolution.

Format

Sn

Parameters

	Integration Time	Period	Resolution
S0	416µsec	Fast	4-digit
S1	4msec	Medium	5-digit
S2	16.67msec	Line Cycle (60Hz)	5-digit
S3	20msec	Line Cycle (50Hz)	5-digit

Default

Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selection. A J0X command sets the instrument to S0 (416µsec integration time, 4-digit resolution).

Description

The S command controls the A/D hardware integration time during each measure phase and the display resolution of the source-measure unit. The integration times offer a tradeoff among speed, resolution, and noise rejection.

Programming Notes

1. For reducing the effect of line cycle noise at low current levels, select the appropriate line cycle integration time. Changing the ac line frequency with a front panel menu selection will change the integration time, if necessary. For example, a line frequency change from 60Hz to 50Hz also changes the integration time from 16.67msec (S2) to 20msec (S3).
2. The time interval between readings in a sweep is determined by the default delay, the dc or sweep delay, and the integration time.
3. If a pulsed sweep is in the buffer, changing the integration time causes the instrument to recalculate the delay times to maintain the specified t_{ON} and t_{OFF}.
4. The conversions filtered are per the selected integration time.
5. The warning condition for the S command is described in the U9 warning status word (see paragraph 3.6.19).

Programming Examples

```
10    OUTPUT 716;"S1X"                 ! Select 4msec reading time.
20    OUTPUT 716;"S2P5X"               ! Select line cycle integration and
                                         32 reading filter
```

3.6.18 T — Trigger Configuration

Purpose

To specify the origin and effect of an input trigger, and when output triggers are generated.

Format

T(origin),(in),(out),(end)

Parameters

origin — Specifies the origin of input triggers:

0 = IEEE X
1 = IEEE GET
2 = IEEE Talk
3 = External (TRIGGER IN pulse)
4 = Immediate only (front panel MANUAL key or H0X command)

in — Specifies the effect of an input trigger:

0 = Continuous (no trigger needed to continue S-D-M cycles)
1 = ^SRC DLY MSR (trigger starts source phase)
2 = SRC^DLY MSR (trigger starts delay phase)
3 = ^SRC^DLY MSR
4 = SRC DLY^MSR (trigger starts measure phase)
5 = ^SRC DLY^MSR
6 = SRC^DLY^MSR
7 = ^SRC^DLY^MSR
8 = ^Single pulse

out — Specifies when an output trigger is generated:

0 = None during sweep
1 = SRC^DLY MSR (end of source phase)
2 = SRC DLY^MSR (end of delay phase)
3 = SRC^DLY^MSR
4 = SRC DLY MSR^ (end of measure phase)
5 = SRC^DLY MSR^
6 = SRC DLY^MSR^
7 = SRC^DLY^MSR^
8 = Pulse end^

end — Sweep End^ trigger out:

0 = Disabled
1 = Enabled

Default

Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selections. J0X command sets the instrument to T4,0,0,0 (origin is immediate only, no trigger needed to continue S-D-M cycle, no output trigger generated during a sweep, no sweep end trigger).

Description

The trigger configuration command determines the input trigger origin, the effect of an input trigger, and when an output trigger is generated.

The trigger origin can be over the bus, from an external trigger pulse, or from the front panel.

An input trigger can be set in a continuous or non-continuous mode. Continuous triggering requires only one trigger to complete a sweep. Non-continuous triggers can be programmed to start the source, delay, or measure phases, or any combination of phases. A single pulse input trigger is intended for use with pulsed sweeps, where each trigger processes the t_{ON} and t_{OFF} times of a single pulse (see Figure 3-13).

Output triggers can be generated after each phase or combination of phases in the S-D-M cycle. When the pulse end trigger is selected, an output trigger occurs after the measurement has been completed in the t_{OFF} time of a pulsed sweep.

A sweep end output trigger can be programmed by itself or with another output trigger selection. When the sweep end trigger is selected, a single output trigger is generated after the sweep has returned to the bias level. This is shown for a pulsed sweep in Figure 3-13.

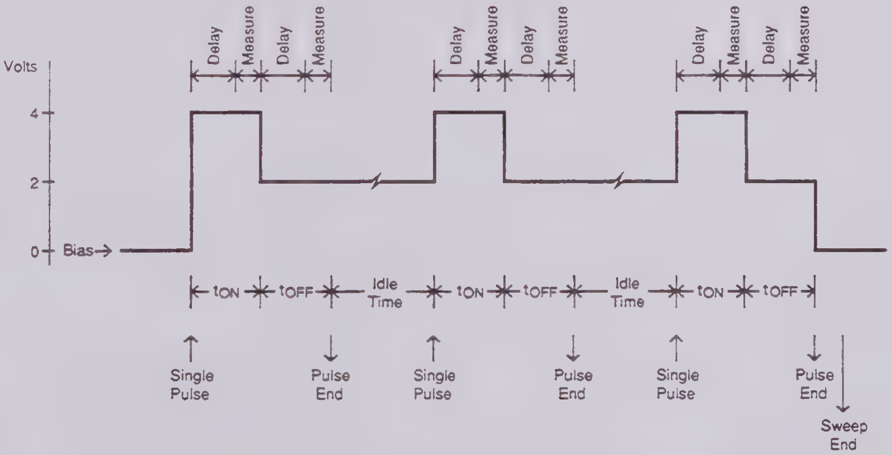
Programming Notes

1. It is good programming practice to disable triggers before changing the trigger origin.
2. If the instrument is triggered while processing a previous command (i.e., during the hold-off time), it displays a PENDING TRIGGER message. The trigger will be acted upon when hold-off has completed.
3. If the instrument is triggered while processing a previous trigger, it displays a TRIG OVERRUN message and the received trigger is ignored.
4. For trigger on X, the A/D conversion time is dependent on when the trigger is configured, since the instrument is triggered by the X character that is sent when programming the trigger origin.
5. For trigger on talk, the A/D conversion time is dependent on when data is requested. To trigger the unit, you must send the talk command derived from the correct primary address. (The factory default address is 16.) Trigger on talk does not occur when the instrument becomes a talker, but rather as the controller requests the first byte of data from the unit.
6. For trigger on GET, the A/D conversion time is independent of when the trigger is configured and when data is requested. Trigger on GET allows the fastest IEEE-488 triggering response.
7. Front panel triggering with the MANUAL key and bus triggering with the H0X command are always enabled regardless of the programmed trigger origin. However, the front panel keys are locked out if the unit is in remote (RMT on). To restore local operation in this case, press the LOCAL key.
8. Executing the trigger control (R), trigger configuration (T), or source and function (F) commands place the unit in an untriggered state.
9. Refer to the Model 236/237/238 Application Manual for suggestions on using triggers with multiple source-measure units.
10. With non-continuous triggers, an additional input trigger is needed after the measure phase of the last sweep point to return to the bias value.
11. While in continuous triggering of the dc mode, the unit can be reprogrammed without having to retrigger it.
12. Valid triggers received after programming continuous triggers are ignored.

13. When trigger on Talk is selected, an ENTER statement triggers the sweep and gets data from the unit. With certain combinations of input trigger effects, the single trigger provided by an ENTER statement is not sufficient to complete a sweep or an individual S–D–M cycle and the bus will hang. For example, ^SRC DLY MSR with all lines selected, or ^SRC DLY^MSR with a single line or all lines selected, requires more than one trigger in order to send measurement data.

Programming Examples

```
 10   REMOTE 716                 !
 20   OUTPUT 716;“R0X”           ! Disable triggers
 30   OUTPUT 716;“T2,0,4,0X”     ! Set to trigger on talk, trigger out
                                   at end of measure
 40   OUTPUT 716;“R1X”           ! Enable triggers
 50   SEND 7; TALK 16            ! Make unit a talker
 60   ENTER 716; A$              ! Trigger sweep by addressing
                                   unit to talk.
 70   OUTPUT 716;“R0X”           ! Disable triggers
 80   OUTPUT 716;“T1,,,X”        ! Change to trigger on GET
 90   OUTPUT 716;“R1X”           ! Enable triggers
100   TRIGGER 716                ! Trigger on GET
110   OUTPUT 716;“T0,,,X”        ! Change to trigger on X, and trig-
                                   ger on X
120   END
```



Sweep Point	Source Value	tON / tOFF
1	4V	100 msec
2	2V	100 msec
3	4V	100 msec
4	2V	100 msec
5	4V	100 msec
6	2V	100 msec

B2, 2, 0
Q3, 4, 2, 3, 100, 100
B0, 2, 0
T1, 8, 8, 1

Figure 3-13. Pulsed Sweep Triggers and Sweep End Trigger

3.6.19 U – Status

Purpose

To obtain instrument status and configuration.

Format

Un

Parameters

U0	Send model number and firmware revision
U1	Send error status word
U2	Send stored ASCII string ("D2" command string)
U3	Send machine status word
U4	Send measurement parameters
U5	Send compliance value
U6	Send suppression value
U7	Send calibration status word
U8	Send defined sweep size
U9	Send warning status word
U10	Send first sweep point in compliance
U11	Send sweep measure size

Description

By sending the appropriate U command and then addressing the instrument to talk as with normal data, you can obtain information on machine status, error conditions, and other data. The information is transmitted only once for each U command.

U0 — Model Number and Firmware Revision

The response to a U0 command is an 8-character ASCII string denoting the instrument model number (236, 237, or 238) and firmware revision level, as shown in Figure 3-14.

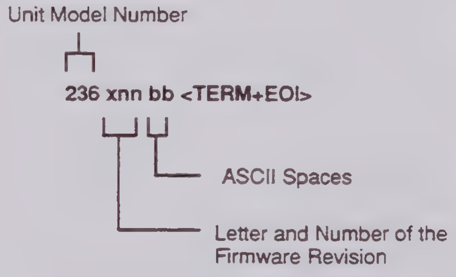


Figure 3-14. U0 Model Number and Firmware Revision

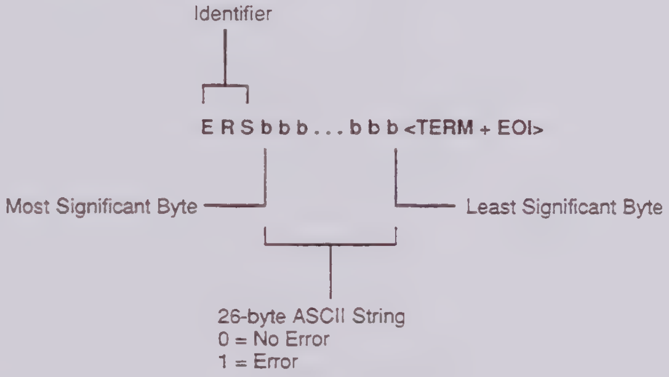
For example, a firmware revision level of A1 for a Model 237 would be sent as follows:

237A01

It is sent with two trailing spaces plus the terminator and EOI (unless disabled with the K command).

U1 — Error Status Word

The U1 command allows access to Model 236/237/238 error conditions. The error status word (Figure 3-15) is actually a string of ASCII characters representing binary bit positions. Reading the U1 status, a DCL or SDC, or a J0X command clears the bits. An error condition is flagged in the serial poll byte while any error bits in the error status word are set. The complete command string is ignored if an IDDC, IDDCO, or Not In Remote error occurs. The instrument can be programmed to generate an SRQ when an error condition occurs (see paragraph 3.6.11).



Most Significant Byte	Trigger Overrun
	IDDC
	IDDCO
	Interlock Present
	Illegal Measure Range
	Illegal Source Range
	Invalid Sweep Mix
	Log Cannot Cross Zero
	Autoranging Source with Pulse Sweep
	In Calibration
	In Standby
	Unit is a 236
	IOU DPRAM Failed
	IOU EEROM Failed
	IOU Cal Checksum Error
	DPRAM Lockup
	DPRAM Link Error
	Cal ADC Zero Error
	Cal ADC Gain Error
	Cal SRC Zero Error
	Cal SRC Gain Error
	Cal Common Mode Error
	Cal Compliance Error
	Cal Value Error
	Cal Constants Error
Least Significant Byte	Cal Invalid Error

Figure 3-15. U1 Error Status Word

The various bits in the U1 error status word are set when the following conditions are present:

played (CAL ADC ZERO, CAL ADC GAIN, CAL SRC ZERO, or CAL SRC GAIN), and a default cal constant value is substituted.

Cal. Common Mode Error — Set when there is an error in calibrating the common mode adjustment. The CAL MODE ERR message is displayed.

Cal. Compliance Error — Set if compliance occurs during a calibration procedure. The CAL COMPLI message is displayed.

Cal. Value Error — Set when the entered value of a cal constant is outside the expected value for the present step. The message CAL VALUE ERR is displayed; check the specified value sent with the C command and re-enter.

Cal. Constants Error — Set when the power–up verification of the cal constants finds one or more values outside of predetermined limits. The message CAL CONSTANTS ERR is displayed; default value(s) are used.

Cal. Invalid Error — Set when one or more cal errors (Cal. ADC Zero, Cal. ADC Gain, Cal. SRC Zero, Cal. SRC Gain, Cal. Mode, Cal. Compliance) are present on power-up, factory initialization DCL, or SDC. The message CAL INVALID ERR is displayed.

U2 — Stored Message

The U2 command is for reading back the last ASCII message that was stored with the D2 command. The message is in the form shown in Figure 3-16. Up to 18 characters may be in the message.

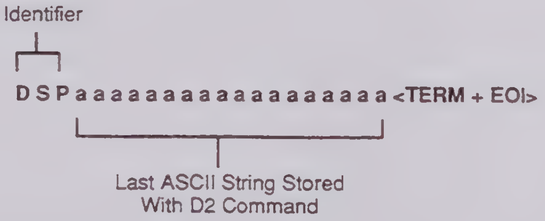
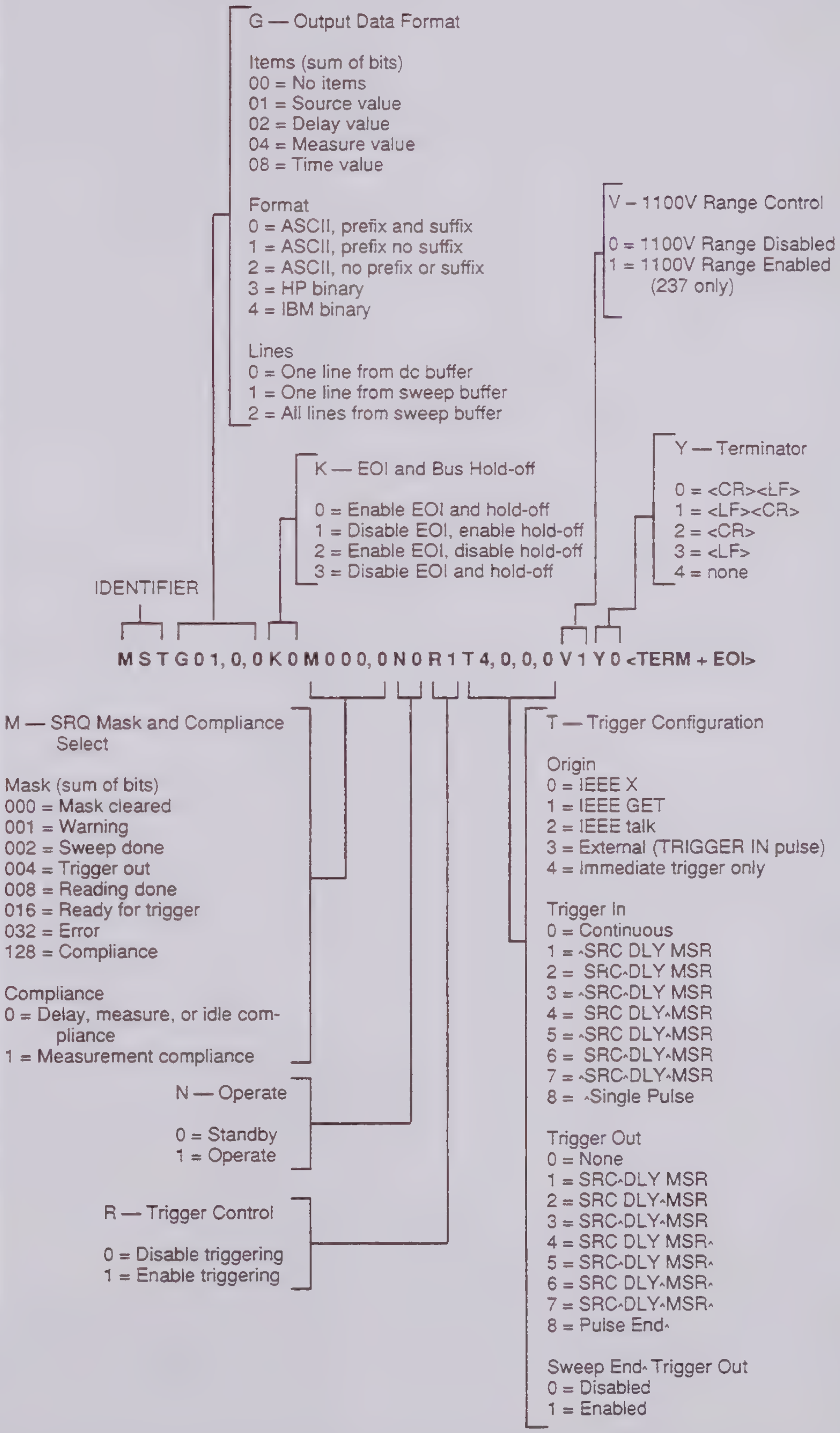


Figure 3-16. U2 Stored ASCII String

U3 — Machine Status

The format of the U3 machine status word is shown in Figure 3-17. After the identifier MST (machine status), the letters correspond to the modes programmed by the respective device-dependent commands. Note that all returned values correspond to the programmed numeric values.



G — Output Data Format

Items (sum of bits)
00 = No items
01 = Source value
02 = Delay value
04 = Measure value
08 = Time value

Format
0 = ASCII, prefix and suffix
1 = ASCII, prefix no suffix
2 = ASCII, no prefix or suffix
3 = HP binary
4 = IBM binary

Lines
0 = One line from dc buffer
1 = One line from sweep buffer
2 = All lines from sweep buffer

V – 1100V Range Control

0 = 1100V Range Disabled
1 = 1100V Range Enabled (237 only)

K — EOI and Bus Hold-off

0 = Enable EOI and hold-off
1 = Disable EOI, enable hold-off
2 = Enable EOI, disable hold-off
3 = Disable EOI and hold-off

Y — Terminator

0 = <CR><LF>
1 = <LF><CR>
2 = <CR>
3 = <LF>
4 = none

IDENTIFIER

M S T G 0 1, 0, 0 K 0 M 0 0 0, 0 N 0 R 1 T 4, 0, 0, 0 V 1 Y 0 <TERM + EOI>

M — SRQ Mask and Compliance Select

Mask (sum of bits)
000 = Mask cleared
001 = Warning
002 = Sweep done
004 = Trigger out
008 = Reading done
016 = Ready for trigger
032 = Error
128 = Compliance

Compliance
0 = Delay, measure, or idle compliance
1 = Measurement compliance

N — Operate

0 = Standby
1 = Operate

R — Trigger Control

0 = Disable triggering
1 = Enable triggering

T — Trigger Configuration

Origin
0 = IEEE X
1 = IEEE GET
2 = IEEE talk
3 = External (TRIGGER IN pulse)
4 = Immediate trigger only

Trigger In
0 = Continuous
1 = ^SRC DLY MSR
2 = SRC^DLY MSR
3 = ^SRC^DLY MSR
4 = SRC DLY^MSR
5 = ^SRC DLY^MSR
6 = SRC^DLY^MSR
7 = ^SRC^DLY^MSR
8 = ^Single Pulse

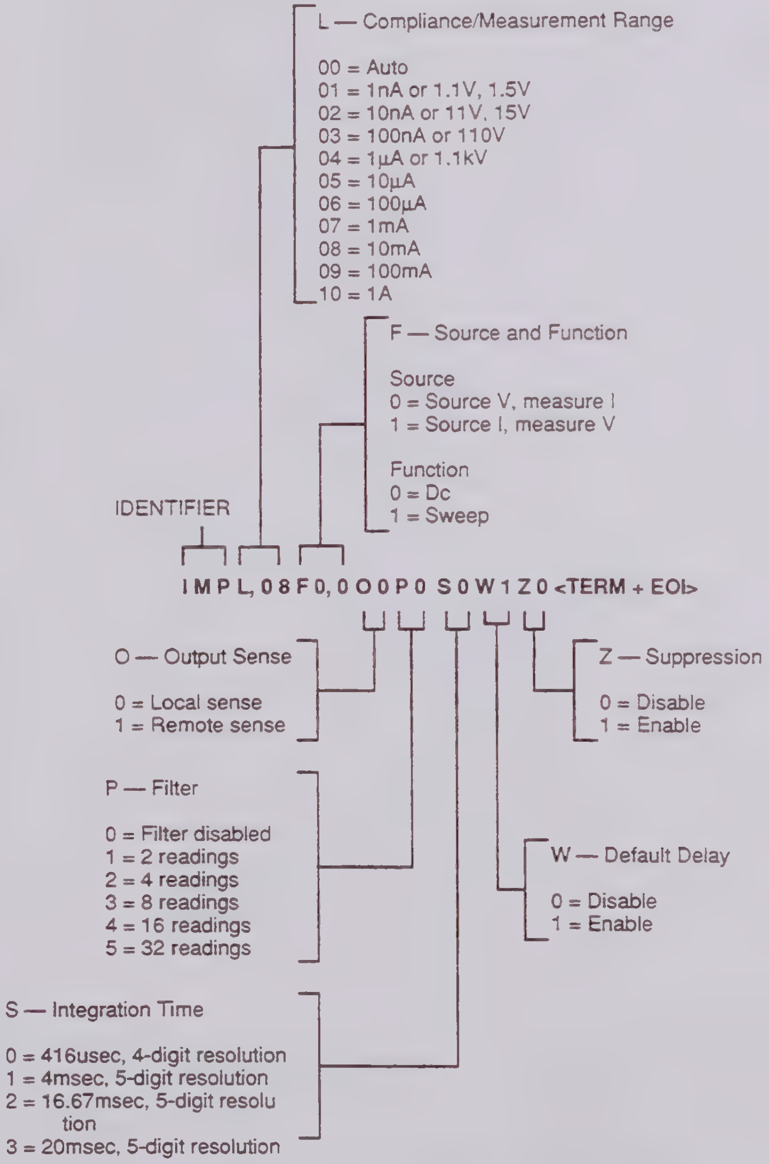
Trigger Out
0 = None
1 = SRC^DLY MSR
2 = SRC DLY^MSR
3 = SRC^DLY^MSR
4 = SRC DLY MSR^
5 = SRC^DLY MSR^
6 = SRC DLY^MSR^
7 = SRC^DLY^MSR^
8 = Pulse End^

Sweep End^ Trigger Out
0 = Disabled
1 = Enabled

Figure 3-17. U3 Machine Status Word (Factory Default Conditions Shown)

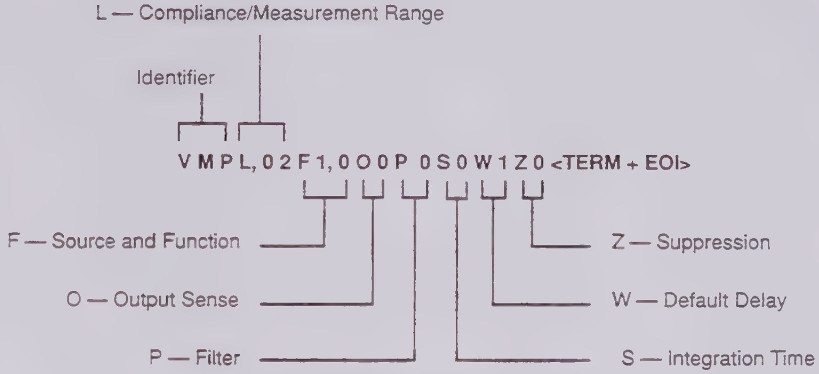
U4 — Measurement Parameters

The U4 command allows access to the programmed measurement parameters. The format for the U4 word is shown in Figure 3-18. After the identifier IMP (current measurement parameters) or VMP (voltage measurement parameters), the letters correspond to device-dependent commands that are associated with the measure phase. Note that all returned values correspond to the programmed numeric values.


L — Compliance/Measurement Range
00 = Auto
01 = 1nA or 1.1V, 1.5V
02 = 10nA or 11V, 15V
03 = 100nA or 110V
04 = 1μA or 1.1kV
05 = 10μA
06 = 100μA
07 = 1mA
08 = 10mA
09 = 100mA
10 = 1A
F — Source and Function
Source
0 = Source V, measure I
1 = Source I, measure V
Function
0 = Dc
1 = Sweep
IDENTIFIER
IMPL,08F0,0O0P0 S0W1Z0<TERM + EOI>
O — Output Sense
0 = Local sense
1 = Remote sense
Z — Suppression
0 = Disable
1 = Enable
P — Filter
0 = Filter disabled
1 = 2 readings
2 = 4 readings
3 = 8 readings
4 = 16 readings
5 = 32 readings
W — Default Delay
0 = Disable
1 = Enable
S — Integration Time
0 = 416usec, 4-digit resolution
1 = 4msec, 5-digit resolution
2 = 16.67msec, 5-digit resolution
3 = 20msec, 5-digit resolution

A. CURRENT MEASUREMENT PARAMETERS

Figure 3-18. U4 Measurement Parameters (Factory Default Conditions Shown)

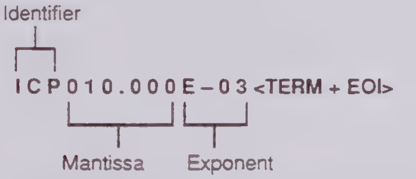

L — Compliance/Measurement Range
Identifier
VMPL,02F1,0O0P0S0W1Z0<TERM+EOI>
F — Source and Function
O — Output Sense
P — Filter
Z — Suppression
W — Default Delay
S — Integration Time

**B. Voltage Measurement Parameters
(see Figure 28A for parameter descriptions)**

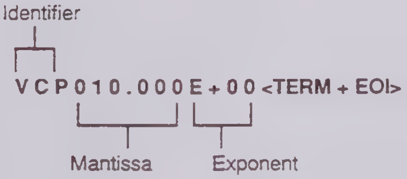
U4 Measurement Parameters (Factory Default Conditions Shown) (Cont.)

U5 — Compliance Value

The U5 command allows access to the programmed compliance level and is formatted as shown in Figure 3-19 for the current or voltage values.


Identifier
ICP010.000E−03<TERM+EOI>
Mantissa
Exponent

A. Compliance Value for Current Measurements

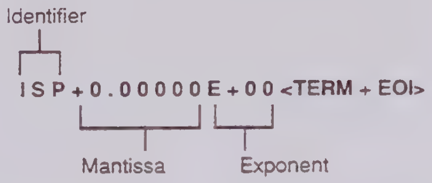

Identifier
VCP010.000E+00<TERM+EOI>
Mantissa
Exponent

B. Compliance Value for Voltage Measurements

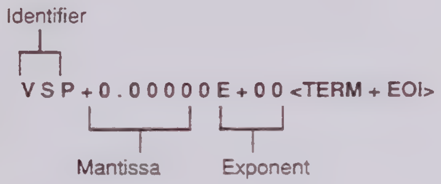
Figure 3-19. U5 Compliance Value (Factory Default Conditions Shown)

U6 — Suppression Value

The U6 command allows access to the programmed suppression value and is formatted as shown in Figure 3-20 for current or voltage.


Identifier
ISP+0.00000E+00<TERM + EOI>
Mantissa
Exponent

A. Suppression Value for Current Measurements


Identifier
VSP+0.00000E+00<TERM + EOI>
Mantissa
Exponent

B. Suppression Value for Voltage Measurements

Figure 3-20. U6 Suppression Value (Factory Default Conditions Shown)

U7 — Calibration Status Word

The U7 command requests the instrument to output the present calibration step, position of CAL LOCK switch, and calibration status as shown in Figure 3-21.

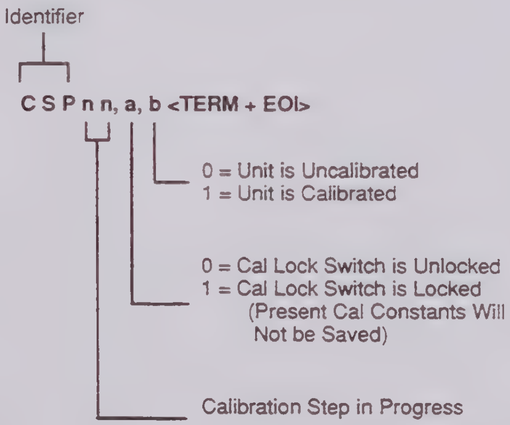

Identifier
CSPnn, a, b <TERM + EOI>
0 = Unit is Uncalibrated
1 = Unit is Calibrated
0 = Cal Lock Switch is Unlocked
1 = Cal Lock Switch is Locked (Present Cal Constants Will Not be Saved)
Calibration Step in Progress

Figure 3-21. U7 Calibration Status Word

U8 — Defined Sweep Size

The U8 command is used to indicate the number of source values in the sweep buffer and is formatted as shown in Figure 3-22.

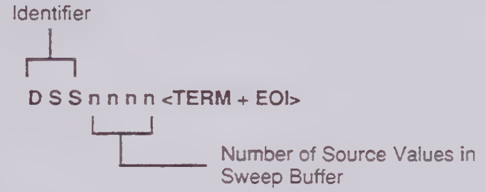
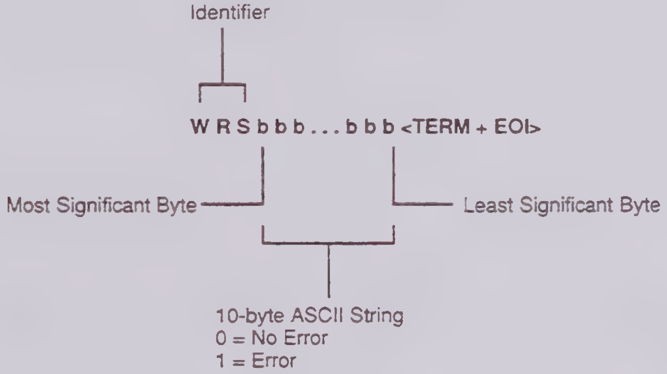

Identifier
D S S n n n n <TERM + EOI>
Number of Source Values in Sweep Buffer

Figure 3-22. U8 Defined Sweep Size

U9 — Warning Status Word

The U9 command allows access to Model 236/237/238 warning conditions. The warning status word (Figure 3-23) is actually a string of ASCII characters representing binary bit positions. Reading the U9 status, a DCL or SDC, or a J0X command clears the bits. A warning condition is flagged in the serial poll byte while any warning bits in the warning status word are set. The instrument can be programmed to generate an SRQ when a warning condition occurs (see paragraph 3.6.11).


Identifier
W R S b b b . . . b b b <TERM + EOI>
Most Significant Byte
Least Significant Byte
10-byte ASCII String
0 = No Error
1 = Error

Most Significant Byte	Uncalibrated
	Temporary Cal
	Value Out of Range
	Sweep Buffer Filled
	No Sweep Points, Must Create Sweep Points
	Pulse Times Not Met
	Not In Remote
	Measure Range Changed Due to 1kV/100mA or 110V/1A Range Select
	Measurement Overflow (OFLO)/Sweep Aborted
Least Significant Byte	Pending Trigger

Figure 3-23. U9 Warning Status Word

The various bits in the U9 warning status word are set when the following conditions are present:

Uncalibrated — Set when the unit detects that illegal cal constants are stored in EEROM. The message UNCALIBRATED is displayed; the Source/Measure LED blinks.

Temporary Cal — Set when calibration mode is entered or exited when the CAL LOCK button is in the LOCKED position. The message TEMPORARY CAL is displayed; entered cal constants are saved in volatile RAM upon exit of cal procedure (C59X) and thus are cleared when power is cycled.

Value Is Out of Range — Set when one of the following conditions exist:

- The selected dc or sweep source value exceeds the source range.
- The selected compliance value exceeds the measurement range.
- The step value is too small for the selected range.
- The step value is more than twice the selected range.

The message VALUE OUT OF RANGE is displayed. With the first two conditions, the maximum (signed) value for the specified range is used. For the third condition, a value of zero is used. (A step of zero yields a buffer filled with one source value for linear stair sweeps or two source values for linear stair pulsed sweeps.) With the last condition, a step value equal to twice the selected range is used (e.g., 22V for the 11V range).

Note that a value out of range warning is retained through a source transition, as follows:

```
10  REMOTE 716
20  OUTPUT 716;"F0,0X"        ! Source V
30  OUTPUT 716; "B2,1,X"      ! Program 2V on 1.1V or 1.5V range, get VALUE
                                OUT OF RANGE
40  OUTPUT 716; "F1,0X"       ! Source I
50  WAIT 3                    ! Wait for message to go away
60  OUTPUT 716; "F0,0X"       ! Source V, get VALUE OUT OF RANGE from pre-
                                vious B command
70  END
```

Sweep Buffer Filled — Set when the number of generated points exceeds the buffer capacity (Q command). A BUFFER FILLED message is displayed; generated points are preserved up to buffer capacity of 1000.

No Sweep Points; Must Create Sweep — Set when an attempt is made to modify a non-existent sweep with an A command or append a non-existent sweep with a Q6 through Q11 command. Also set if a trigger for a sweep occurs and there are no sweep points. The message MUST CREATE SWEEP is displayed; no sweep points are generated.

Pulse Times Not Met — Set when the specified pulse times (t_{ON} and t_{OFF}) cannot be met (P, Q, S, and W commands). Also, for pulsed sweeps, set if autorange measure is programmed (L command) and the pulse times might not be not long enough. The message PULSE TIME NOT MET is displayed, and, if necessary, the t_{ON}/t_{OFF} times will be extended to the minimum needed to support the waveform create/append or instrument configuration.

Not in Remote — Set when an X command is received over the bus but the Model 236/237/238 is not in remote. The NOT IN REMOTE message is displayed.

Measure Range Changed Due to 1.1kV/100mA or 110V/1A Range Select — Set when the source and measure ranges are in conflict (A, B, F, L, and Q commands). The selected ranges cannot be 1.1kV and 100mA (237), or 110V and 1A (238) simultaneously, either when sourcing voltage, measuring current, or when sourcing current, measuring voltage for either dc or sweep operation. The instrument displays a MEAS RANGE CHANGED message and the measure range is lowered. A VALUE OUT OF RANGE message is displayed as the compliance value is applied to the lower range.

Measurement Overflow/Sweep Aborted — Set when an external source of power has overloaded the measurement hardware of the Model 236/237/238. A measurement overflow is indicated at 112.5% of full scale range. The message OFLO is displayed in place of the measurement value. Also set when a sweep has aborted (e.g., in response to a command sent while a sweep is in progress).

Pending Trigger — Set when the unit is triggered while it is processing a previous command (e.g., if a front panel trigger is received during the bus hold-off time of a Q command, or if a bus trigger is received while sweep points are being generated from the front panel). A PENDING TRIGGER message is displayed and the trigger is saved until it can be acted upon.

U10 — First Sweep Point in Compliance

The U10 command requests the instrument to search the sweep buffer for the first measurement point that was in compliance. The point is not sent in a fixed format word, but in the output data format previously specified by a G (items), (format), (lines) command (see paragraph 3.6.6). For example, if the source and measure values are the only items of interest (as shown in Figure 3-24), use the following program:

```
10    REMOTE 716
20    OUTPUT 716;"F0,1X"         ! Voltage sweep
30    OUTPUT 716;"G5,0,0X"       ! Source and measure items, prefix
                                   and suffix
40    OUTPUT 716;"U10X"          ! Send first sweep point in compli-
                                   ance
50    ENTER 716;A$               ! Get sweep point
60    PRINT A$                   ! Print source and measure values
70    End
```

When no sweep points are in compliance, or when U10 is programmed while in dc operation, only terminator characters are returned. Note that the "lines" parameter in the G command has no effect on the U10 status word.

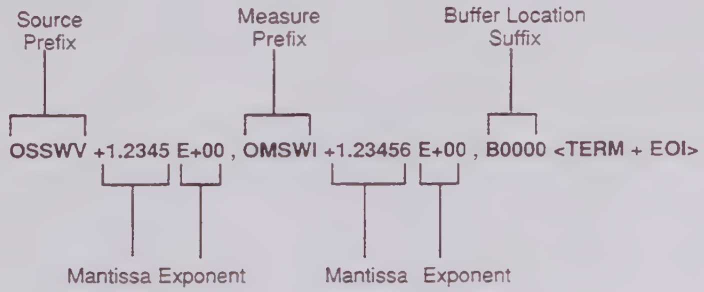

Source Prefix
Measure Prefix
Buffer Location Suffix
OSSWV +1.2345 E+00 , OMSWI +1.23456 E+00 , B0000 <TERM + EOI>
Mantissa
Exponent
Mantissa
Exponent

Figure 3-24. U10 First Sweep Point in Compliance

U11 — Sweep Measure Size

The U11 command indicates the present number of measure values in the sweep buffer and is formatted as shown in Figure 3-25. This information is useful when a sweep has aborted and further measurements are unavailable. The value returned by U10 can be used as the count in a FOR/NEXT loop to obtain single lines of sweep data.

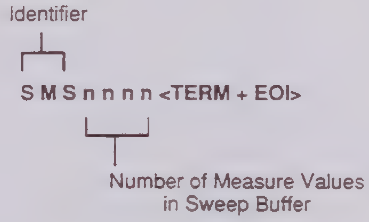

Identifier
S M S n n n n <TERM + EOI>
Number of Measure Values in Sweep Buffer

Figure 3-25. U11 Sweep Measure Size

Programming Note

Requesting any U status word resets the sweep buffer pointer to one.

Programming Example

```
10    DIM Command$[50],Status$[50]      ! Dimension command and status
                                          strings
20    REMOTE 716
30    INPUT "Enter U Command",           ! Get desired U command
      Command$
40    IF LEN(Command$)=0 THEN 100        ! Check for null
50    OUTPUT 716;Command$&"X"            ! Program with U command
60    ENTER 716;Status$                  ! Get status
70    PRINT Status$                      ! Print status
80    PRINT CHR$(128)                    ! Print blank line
90    GOTO 30                            ! Return for next U command
100   END
```

3.6.20 V — 1100V Range Control

Purpose

To control the output of voltages on the 1100V range of a Model 237 Source Measure Unit.

Format

Vn

Parameters

V0	Disable 1100V range
V1	Enable 1100V range

Default

Upon power-up, or after receiving a DCL or SDC command, the Model 237 defaults to the last programmed selection; the Models 236 and 238 default to V0 (1100V range disabled). A J0X command sets Model 237 to V1 (1100V range enabled) and the Models 236 and 238 to V0.

Description

The V command can be used to prevent accidental application of voltages on the 1100V range by a Model 237. This is useful when the output is switched and the maximum switched voltage is specified at less than the maximum output of the Model 237.

If you program a V0 command when the 1100V range is in use, the output goes to 150V or less. If you program a voltage above 110V when the 1100V range has been disabled with V0, the output is set to 110V. (See the Programming Example for details.)

Programming Notes

1. Sending a V command to a Model 236 or 238 is treated as an illegal command (IDDC).
2. Calibrating the 1100V range requires that the range is enabled with the V1 command.

Programming Example

```
REMOTE 716
OUTPUT 716;"J0X"              ! Restore factory defaults
OUTPUT 716;"B200,4,X"         ! Program 200V on 1100V range
OUTPUT 716;"N1X"              ! Place 237 in operate, output =
                                200V
OUTPUT 716;"V0X"              ! Disable 1100V range, output =
                                150V
OUTPUT 716;"B200,4,X"         ! Program 200V on 1100V range,
                                get Illegal Src Range message,
                                output = 150V
OUTPUT 716;"V1X"              ! Enable 1100V range, output 200V
OUTPUT 716;"V0X"              ! Disable 1100V range, output =
                                150V
OUTPUT 716;"B200,3,X"         ! Program 200V on 110V range, get
                                Value Out of Range message,
                                output = 110V
```

```
OUTPUT 716;"V1X"                ! Enable 1100V range, output =
                                  110V
OUTPUT 716;"N0X"                ! Place 237 in standby, output = 0V
```

3.6.21 W — Default Delay

Purpose To enable/disable the default delay of the source-delay-measure cycle.

Format **Wn**

Parameters

W0	Disable default delay
W1	Enable default delay

Default Upon power-up, or after receiving a DCL or SDC command, the instrument defaults to the last programmed selection. A J0X command sets the instrument to W1 (default delay enabled).

Description The W command controls the enabling/disabling of a fixed delay used to compensate for the instrument settling time when measuring resistive loads. See Figure 3-26.

Do not confuse this delay with the dc delay that is programmed with the B command, or the sweep delay that is programmed with the A and Q commands.

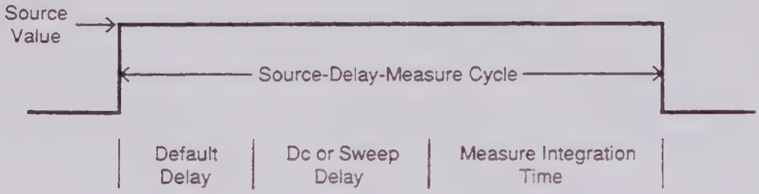
When W1 is sent over the bus, the default delay, which is I-range dependent, is effectively added to the specified dc or sweep delay.

Programming Notes

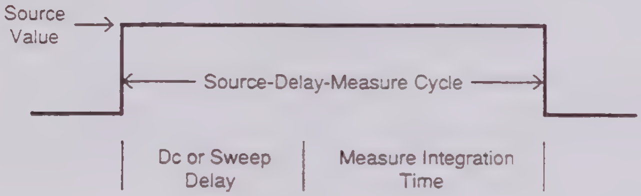
1. Default delay values are listed in the discussion of timing considerations (paragraph 3.7).
2. When measure autoranging is used, the default delays are used whether they are enabled or not with the W command.
3. The warning condition for the W command is discussed in the U9 warning status word (see paragraph 3.6.19).

Programming Example

```
10    OUTPUT 716; "W1X"                    ! Enable default delay.
20    OUTPUT 716; "W0X"                    ! Disable default delay.
```


Source
Value
Source-Delay-Measure Cycle
Default
Delay
Dc or Sweep
Delay
Measure Integration
Time

A. Default Delay Enabled (W1)


Source
Value
Source-Delay-Measure Cycle
Dc or Sweep
Delay
Measure Integration
Time

B. Default Delay Disabled (W0)

Figure 3-26. Default Delay

3.6.22 X — Execute

Purpose

To direct the Model 236/237/238 to execute device-dependent commands received since last X.

Format

<command>X

Parameters

None

Description

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the unit to execute other device-dependent commands such as F (source and function) or P (filter). Usually, the execute character is the last byte in the command string (a number of commands may be grouped together into one string); however, there may be certain cases when it is desirable to send a command string at one time, and then send the execute character later on.

Programming Notes

1. Commands or command strings sent without the X character are not executed at that time, but they are stored in an internal command buffer for later execution. When the X character is finally transmitted, the stored commands are executed, assuming that all commands in the previous string were valid.
2. Commands are not necessarily executed in the order sent (see Table 3-5). To force a particular command sequence, include the X character after each command in the command string.
3. The X character can also be used to trigger, as described in paragraph 3.6.18.

Programming Examples

```
OUTPUT 716;"P1X"          ! Execute single command.
OUTPUT 716;"P0N1X"        ! Execute multiple command
                            string.
OUTPUT 716;"N0XP1X"       ! Force command sequence.
OUTPUT 716;"W1P0S1"       ! Send string without executing.
OUTPUT 716;"X"            ! Execute previous command
                            string.
```

3.6.23 Y — Terminator

Purpose

To select the ASCII terminator sequence that marks the end of the instrument's data string or data word.

Format

Yn

Parameters

Y0	<CR><LF>
Y1	<LF><CR>
Y2	<CR>
Y3	<LF>
Y4	none

Default

Upon power-up, or after receiving a DCL, SDC, or J0X command sets the instrument to Y0 (<CR><LF>).

Description

By using the Y command, you can program the number and type of terminator characters the instrument sends at the end of its data string. Available terminator characters are the commonly used CR (carriage return, ASCII 13) and LF (line feed, ASCII 10) characters. These terminators are recognized by most controllers. Selecting the wrong terminator for the controller could cause the bus to hang.

You also have the option of selecting that no terminators be sent (a common choice for a binary output data format).

Programming Examples

```
OUTPUT 716; "Y1X"          ! Terminate on LF CR.
OUTPUT 716; "Y0X"          ! Restore default terminator.
```

3.6.24 Z — Suppress

Purpose To enable/disable the suppression of subsequent readings with the present measurement.

Format **Zn**

Parameters

Z0	Disable suppression
Z1	Enable suppression

Default Upon power-up, or after receiving a DCL, SDC, or J0X command, the instrument defaults to Z0 (suppression disabled).

Description Suppression allows a stored value to be subtracted from subsequent readings. When suppression is enabled (Z1), the next conversion taken in OPERATE will be internally stored as a baseline. All subsequent readings will be the difference between the stored baseline level and the actual level.

Programming Notes

1. After enabling suppression, check the reading done bit in the serial poll byte to verify that the S-D-M cycle for the baseline value has completed. If this is not done, and the source value is changed before the baseline measurement, an unexpected suppression value will be in effect.
2. It is not necessary to disable suppression before re-enabling it. Hence, multiple Z1 commands can be sent to renew the baseline measurement.
3. Measurements are stored as unsuppressed values. If enabled, suppression is applied when data is being output by the instrument. Suppressed measurements are flagged in output data (see paragraph 3.6.6).
4. Setting a range lower than the stored baseline value will overrange the reading if you go into compliance.
5. If the stored baseline value is +5V on the 11V range of a 236/237, a measured voltage of +6V or more would put the instrument in compliance.
6. The present suppression value can be read with the U6 command.
7. The baseline value maintains its value regardless of range. For example, if a 0.5V measured reading is suppressed on the 1.1V or 1.5V (Model 238) range, it will remain at 0.5V on the 11V, 15V (Model 238), 110V, and 1100V (Model 237) ranges.
8. A suppressed value is not saved for both the voltage source and the current source. The respective baseline will be lost when the sources are toggled.

Programming Example

```
OUTPUT 716; "Z1X"          ! Enable suppression.
OUTPUT 716; "Z0X"          ! Disable suppression.
```

3.7 TIMING CONSIDERATIONS

Timing considerations for IEEE-488 programming include:

- Data transfer rates between the controller and Model 236/237/238 over the IEEE-488 bus.
- Command string parse time within the Source Measure Unit.
- Execution times of the tasks defined by device-dependent commands.

The times needed for these actions are determined by the length of the command string, the types of commands, and the speed of the controller.

Typically, a command string sent to the Model 236/237/238 will transmit at a rate of five characters per millisecond. (Assuming the transfer speed of the controller does not affect the listening rate of the Model 236/237/238.) For example, the command string "Q1,1,10,1,2,50X" will take 3msec to transmit from the controller to the Model 236/237/238.

When the Source Measure Unit is sending data to the controller (e.g., uploading sweep data), the transmission rate will typically be 2.5 characters per millisecond.

The bus hold-off time for each command is the time from receipt of the "X" to "instrument configured". It includes the parsing time and command execution time. Table 3-8 summarizes the bus hold-off times for device-dependent commands.

Table 3-8. Typical Bus Hold-off Times

Description	Command	Time
Modify Sweep List	A1, 1, 1, 1, 2	8.2msec
Bias Operation	B1, 1, 1	18.6msec
Display	D1, 236	7.9msec
	D2, 236	316.3msec
	D0X	14.4msec
Source and Function	F1, 0	64.0msec
Output Data Format	G15, 0, 0	8.3msec
IEEE Immediate Trigger	H0X	14.2msec
Restore Factory Defaults	J0	1.13sec
EOI and Bus Hold-offs	K1	7.2msec
Compliance	L.001, 7	30.6msec
SRQ Mask and Serial Poll Byte	M1, 1	13.1msec
Operate	N1	13.6msec
Output Sense	O1	11.6msec
Filter	P1	13.6msec
Create/Append Sweep List	Q0, 1, 0, 0, 10	71.7msec
	Q0, 1, 2, 1, 1	39.9msec
Trigger Control	R0	7.5msec
Integration Time	S1	28.6msec
	S2	64.5msec
Trigger Configuration	T0, 0, 0, 0	15.5msec
Status	U0	7.5msec
1100V Range Control	V0 or V1	11.6msec
Default Delay	W0	12.6msec
Execute	X	6.4msec
Terminator	Y1	7.5msec
Suppress	Z1	10.7msec

Note: The Model 236/237/238 is placed in power-up default conditions before each command is sent.

3.7.1 Factors Affecting Sweep Times

Basically, there are four phases to programming the instrument, performing a sweep, and transmitting data over the bus:

1. Programming phase: Here, all the necessary operating modes are programmed by sending appropriate commands over the bus. Typically, you will select the bias, sweep waveform type and parameters, reading rate, and trigger configuration.
2. Trigger phase: To perform a sweep, the unit must be triggered in some fashion; that trigger will, of course, depend on the programmed trigger origin. If the instrument is to be synchronized with external equipment, an external trigger origin should be selected. If you intend to trigger the unit from a controller, use one of the IEEE trigger origins (X, GET, or Talk). The best one to use depends on when you want the sweep to occur. With a trigger on X, the sweep starts when the X character is received with the trigger configuration command. A trigger on Talk starts a sweep when the controller requests the output data. A trigger on GET can start a sweep any time after the trigger is configured and before the data is requested. The trigger origins with the fastest response times are External and IEEE GET (<2msec).
3. Sweep phase: During this phase, the instrument cycles through the steps of the sweep waveform and takes readings. The number of readings is programmable.
4. Data transmission phase: Once the sweep has completed and the data is stored in the Model 236/237/238 sweep buffer, data must be transmitted to the computer. There are two methods that can be used: complete sweep data transmission and single line transmission. If your computer can handle a long string of bytes, program the Model 236/237/238 to dump all lines of sweep data.

3.7.2 Optimizing Source and Measurement Speed

The length of a source-delay-measure cycle depends on several factors, among them are:

- Source settling time — Response time to a source value change to within a rated accuracy.
- Source range changing times, if necessary.
- Measurement settling time — Response time to a measurement change to within a rated accuracy.
- Measurement integration time — Interval between analog to digital conversions.
- Measure range changing times, if necessary.

These factors become critical at low current levels because of the following:

1. There are large range elements for low currents, consequently the time constants (τ) are long. The default delays are approximately equal to 5τ (see Table 3-9). This allows adequate settling time in most cases, but it can be extended with the dc or sweep delay. Note that the default delay in effect is based on the I-range (when sourcing voltage, value is measure range dependent, when sourcing current, value is source range dependent).
2. Long time constants also yield longer range changing times.
3. Line cycle integration is often necessary at low current levels to reject line frequency noise and get repeatable low current data. This is the slowest integration time available (16.67msec or 20msec).
4. Dielectric absorption, due to the capacitance of the instrument and the test circuit, causes the current to approach a steady-state value slower than expected. It is especially evident at hundreds of femtoamps or below. Figure 3-27 shows the percent of range settling versus multiples of time constants for a 10V step. The ideal case is a straight line. The worst case is the 1nA range, where at about 0.04% of range (400fA), a dielectric tail exists at 11.5τ. The 10nA range shows about 0.004% at 11.5τ, the 100nA range about 0.0004%. Higher ranges approximate the ideal case. Capacitance of the test circuit itself will extend the settling time and must be accounted for in the sweep or dc delay.

Table 3-9. Default Delays

I-source or I-measure Range	Default Delay
1nA	360msec
10nA	75msec
100nA	20msec
1μA	5msec
10μA	2msec
100μA	0msec
1mA	0msec
10mA	0msec
100mA	0msec
1A	0msec

Note: If default delay is disabled, use value of 0.

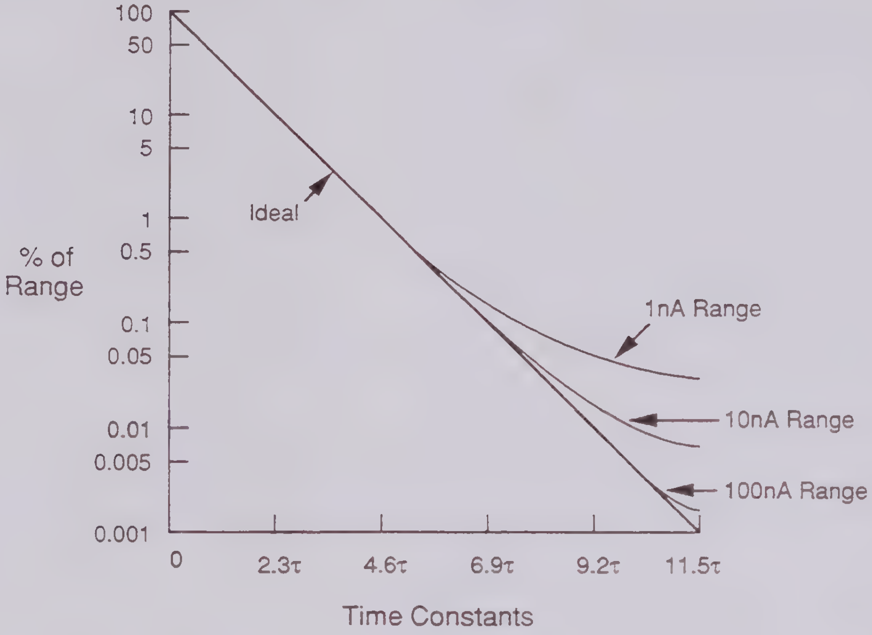


Figure 3-27. Percentage of Range Settling vs. Time Constants for a 10V Step

Minimizing Source Settling Times

Figure 3-28 shows the source-measure unit as a voltage source with the associated current measure range elements. R_S is the current sensing resistor; C_C and C_L are compensation capacitors. Table 3-10 lists the values of these elements for the various I-ranges. RUT and C_{EXT} represent the resistance and capacitance of the load.

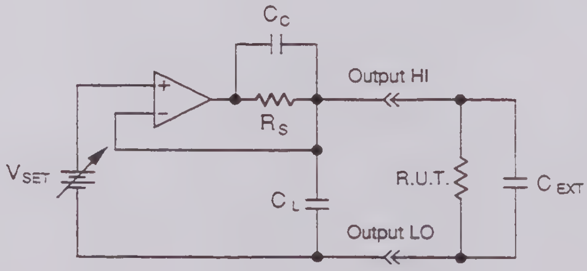


Figure 3-28. Source-Measure Unit as a Voltage Source

When operated as a voltage source, V_{SET} is forced across RUT. For this to happen, C_L and C_{EXT} have to be charged. At low compliance currents, ($I = Cdv/dt$), $\Delta V/\Delta T$ can be quite slow. Therefore, to optimize the charging time, set the compliance value as high as possible, without compromising protection of the test system.

Table 3-10. Range Elements

I-range	C_C	C_L	R_S
1nA	6pF	11pF	10GΩ
10nA	13pF	11pF	1GΩ
100nA	34pF	34pF	100MΩ
1μA	100pF	110pF	10MΩ
10μA	270pF	280pF	1MΩ
100μA	270pF	280pF	100kΩ
1mA	270pF	280pF	10kΩ
10mA	270pF	280pF	1kΩ
100mA	16pF	110pF	100Ω
1A	16pF	110pF	1Ω

Once V_{SET} is across the load, the current measure combination of R_S and C_C has to settle out ($\tau = R_S \times C_C$, or approximately 1/5 of the default delay). Any dielectric absorption in RUT or C_{EXT} will further extend the settling time.

Figure 3-29 shows the source-measure unit as a current source. Note that the range elements and values are the same, but the amplifier is configured differently. When operated as a current source, V_{SET} is forced across R_S and C_C because the inverting input of the op amp is at virtual ground. Therefore, a constant current (V_{SET}/R_S) flows through the load. The voltage across RUT will settle as a function of all circuit elements and can be approximated by:

$$\tau = (RUT) \times (C_L + C_{EXT})$$

As an example, if RUT is 10GΩ and C_L is 11pF, which is the 1nA range, there is a 110msec time constant. Adding 11pF of external capacitance doubles the time constant.

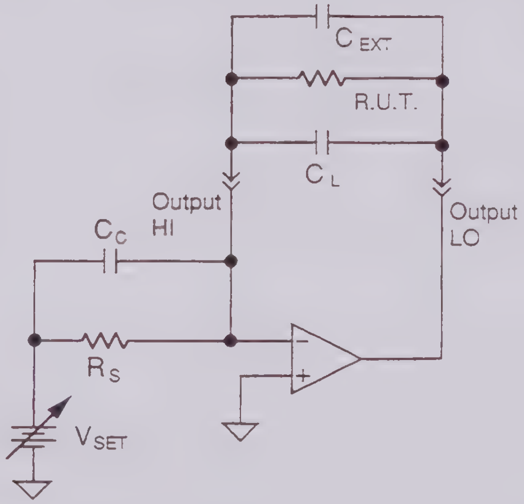


Figure 3-29. Source-Measure Unit as a Current Source

Guarding

One way to minimize settling time is to use guarding. To confirm this, an example test was performed on a 10GΩ resistor in a Model 8006 Test Fixture, where a 1nA forced current should yield approximately 10V output.

In the first case, Output LO, the panel shields, and the module shields were tied to earth. This puts all the stray capacitance inside the test fixture, across the leads of the resistor in the test socket. The output was stepped to 1nA; it took 435msec to reach 9V. For the second case, the panel and module shields were connected to Guard. With this simple change, the time to 9V decreased to 220msec.

Current Overshoot

With the source-measure unit configured as a current source, there is a possibility for current overshoot when RUT is less than R_S (since $C_C \approx C_L$, and assuming C_{EXT} is negligible). The ac gain is approximately −1, but the dc gain is less than −1.

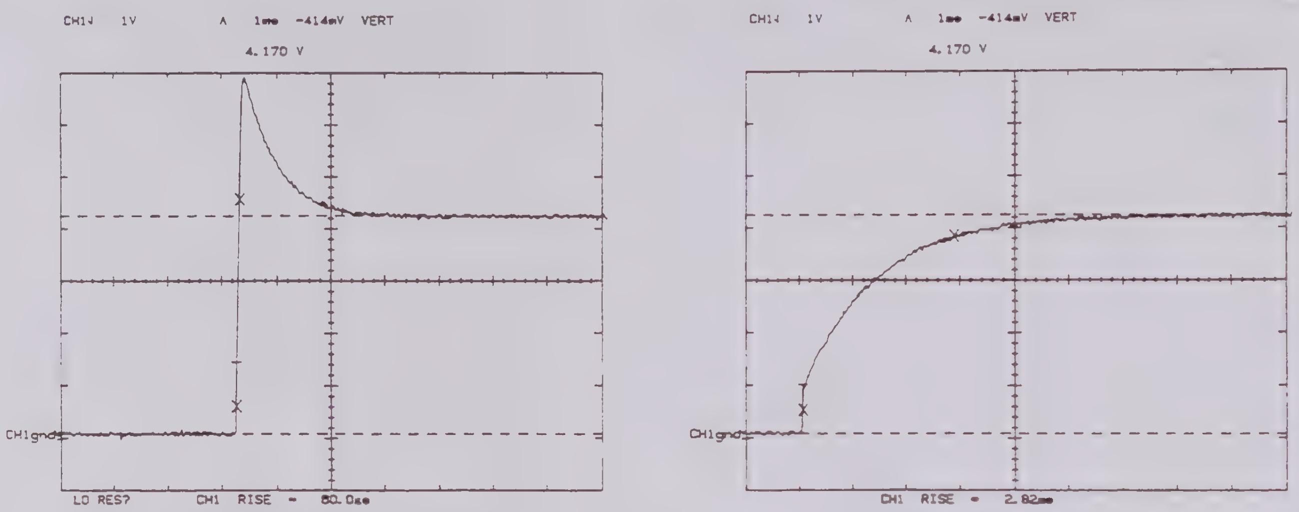
For example, if RUT is one-tenth of R_S, the ac gain will be 1 and the dc gain will be 0.1. With a step of V_{SET}, the output will try to go to 1 and then come back down to 0.1. There are several ways to eliminate this, among them are:

- Increase C_{EXT} to match the time constants. This may be impractical.
- Go up to the next current range and use a smaller percentage of the range. For example, use 10% of the range above instead of 100% of the present range. This makes R_S smaller, so now it is less than RUT. The disadvantage of a higher range is less source resolution.

Figure 3-30 illustrates the second method. Figure 3-30A shows 1μA forced into 4.17MΩ on the 1μA range (with a 10MΩ range resistor). There is about a 50% overshoot. In Figure 3-30B, the 10μA range is used (with a 1MΩ range resistor) and the overshoot has been eliminated.

Source Range Changes

The last consideration of the source phase is if the source has to change ranges during an S-D-M cycle. Table 3-11 lists the times that must be accounted for with V-source and I-source range changes.



A. 1µA into 4.17MΩ on 1µA Range

B. 1µA into 4.17MΩ on 10µA Range

Figure 3-30. Current Overshoot

Table 3-11. Typical Source Range Change Times

Present Range	1nA – 100nA	1µA – 10mA	Next Range 100mA	1A	1.1V, 11V; 1.5V, 15V	110V, 1100V
1nA – 100nA	23msec	5msec	3msec	10msec	—	—
1µA – 10mA	23msec	5msec	3msec	10msec	—	—
100mA	24msec	5msec	—	10msec	—	—
1A	36msec	18msec	14msec	—	—	—
1.1V, 11V; 1.5V, 15V	—	—	—	—	5msec	10msec
110V, 1100V	—	—	—	—	10msec	5msec

Minimizing Measurement Time

The selections for A/D hardware integration times during each measure phase are listed in Table 3-12. The measure times are with the filter disabled and a fixed measure range. Your throughput can be optimized by knowing which integration time and measure range to use. For maximum throughput, use only as much resolution as you need.

Table 3-12. Measure Times

Integration Time	Resolution	Measure Time
416µsec	4-digit	1msec
4.0msec	5-digit	5msec
16.67msec	5-digit	23msec
20.0msec	5-digit	27msec

As an example, consider a measurement requiring 1pA sensitivity, which can be made on the 1nA or 10nA range. Assuming the external system noise is low, you could use 416µsec integration time (4-digit resolution). From Figure 3-27, the 1nA range settles to 0.1% (1pA) in approximately 7.7τ. The τ from Table 3-10 is 60msec, so that yields 462msec. Adding the 1msec measurement time from Table 3-12 gives a total of 463msec, or about 2.2 readings per second.

On the 10nA range, with a 4msec integration time (5-digit resolution), the range settles to 0.01% (1pA) in about 10.1τ. For the 10nA range, that is about 131msec (from Table 3-10). Adding the 6msec measurement time (from Table 3-12) gives 137msec, or approximately 7.3 readings per second.

Measurement Ranging Times

Table 3-13 through Table 3-16 list range change times for I-measure and V-measure for both fixed range and autorange. Typical times are given for 416µsec and 16.67msec integrations. The times are from the start of a range change until a reading is in the buffer, including the measure time (1msec or 24msec).

Determining the range change time for fixed ranges is a simple table look-up of present range and next range. For autoranging, range change times depend on the following factors:

- Integration time
- Starting and ending range
- Source or measure range change
- Direction of range change (up or down)
- Compliance value (when upranging)
- User-programmable sweep delay (assume 0msec for this discussion)
- Default delay (used whether enabled or not with W command)

Autoranging

When a range change is needed and autoranging is selected, the Model 236/237/238 steps by two ranges at the most (a 3-range change has a 2-range step and a 1-range step), except when going to the compliance range, which is done in one step.

When upranging, the instrument goes to the compliance range and comes back downrange as shown in Figure 3-31. The procedure taken when downranging, as shown in Figure 3-32, is just downrange stepping as explained above.

NOTE

If the Model 236/237/238 goes into compliance during autoranging, it waits up to one second to see if it will come out of compliance.

As a final note on autoranging, it is obvious that the fastest range changing is when the current is decreasing from high to low. (The unit will not have to go up to the compliance range and then work it's way back down.) So, for maximum throughput, program a sweep in an order that decreases current.

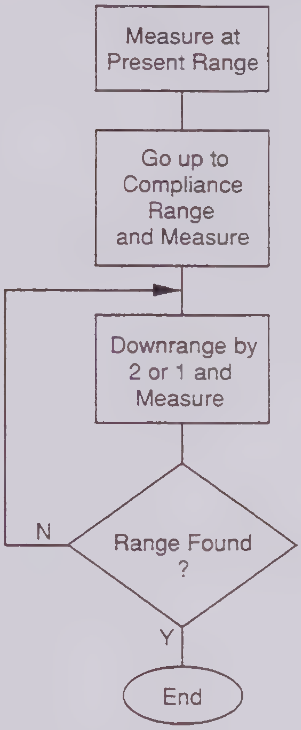

Measure at Present Range
Go up to Compliance Range and Measure
Downrange by 2 or 1 and Measure
N
Range Found ?
Y
End

Figure 3-31. Upranging Steps

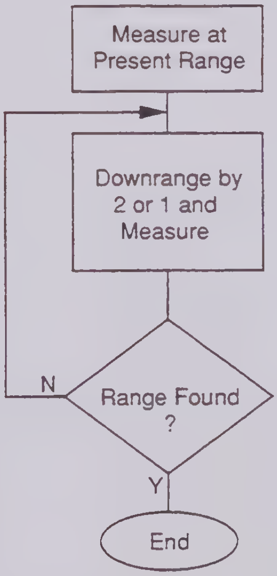


Figure 3-32. Downranging Steps

Table 3-13. Typical I–measure Range Change Times (Fixed Range)

From Range	Integration Time	To Range									
		1nA	**10nA**	**100nA**	**1µA**	**10µA**	**100µA**	**1mA**	**10mA**	**100mA**	**1A**
1nA	16.67msec		153.8	96.2	57.0	52.5	52.4	51.8	51.8	49.5	62.2
	416µsec		115.0	59.6	20.4	16.6	14.6	14.6	14.6	11.8	25.8
10nA	16.67msec	520.0		96.4	56.9	53.6	51.9	51.7	51.8	48.2	62.8
	416µsec	484.0		58.6	20.0	16.7	14.7	14.5	14.6	11.5	25.8
100nA	16.67msec	468.5	178.0		57.1	53.7	52.2	52.2	52.1	49.2	62.8
	416µsec	432.0	139.8		19.75	16.6	14.6	14.6	14.5	11.5	26.2
1µA	16.67msec	451.0	163.2	107.0		54.7	52.9	52.3	52.3	49.5	62.7
	416µsec	411.5	126.8	69.1		16.5	14.6	14.6	14.5	11.5	25.8
10µA	16.67msec	453.0	162.0	104.0	61.3		52.3	52.3	52.3	49.8	63.2
	416µsec	410.4	124.2	66.2	23.8		14.46	14.6	14.5	11.5	25.5
100µA	16.67msec	448.0	158.0	102.4	60.5	56.8		51.6	51.7	48.8	63
	416µsec	409.0	120.4	64.7	22.9	19.6		14.5	14.4	11.4	26.1
1mA	16.67msec	450.5	158.6	103.4	60.2	57.4	54.9		52.1	49.0	62.6
	416µsec	410.4	121.4	65.6	22.9	19.5	17.5		14.6	11.6	25.9
10mA	16.67msec	449.0	159.8	103.2	61.0	57.6	55.5	55.2		49.0	62.6
	416µsec	412.0	120.8	64.9	23.2	19.4	17.4	17.3		11.5	25.5
100mA	16.67msec	440.0	147.8	92.0	58.3	55.5	53.3	53.1	53.1		53.8
	416µsec	398.5	111.0	54.5	20.7	17.5	15.3	15.3	15.3		17.1
1A	16.67msec	445	158	102	70	66	65	65	65	62	
	416µsec	406	120.6	65	33	29.6	28	28	28	24.4	

Note: Range change times are expressed in milliseconds.

Table 3-14. Typical I–measure Range Change Times (Autorange)

		To Range									
From Range	**Integration Time**	**1nA**	**10nA**	**100nA**	**1µA**	**10µA**	**100µA**	**1mA**	**10mA**	**100mA**	**1A**
1nA	16.67msec		435.0	277.0	233.0	168.0	167.8	108.4	50.8	51.0	50.4
	416µsec		240.5	122.8	76.8	51.5	50.9	51.1	31.0	13.5	13.5
10nA	16.67msec	443.0		349.0	233.0	171.0	168.4	108.2	108.2	50.6	50.7
	416µsec	405.0		236.0	92.2	52.4	50.6	30.4	31.0	13.8	13.9
100nA	16.67msec	442.5	154.5		235.0	170.0	168.0	108.4	108.4	50.9	50.5
	416µsec	402.5	119.4		76.4	52.2	50.9	50.7	31.3	14.2	13.8
1µA	16.67msec	599.0	155.0	101.2		170.0	168.2	108.6	108.6	51.0	50.9
	416µsec	524.0	118.5	64.1		52.4	50.8	31.3	31.2	13.6	14.1
10µA	16.67msec	545.0	262.5	101.8	59.7		168.6	108.6	108.6	50.6	50.4
	416µsec	471.5	185.0	67.4	22.2		50.9	31.2	31.3	14.0	13.8
100µA	16.67msec	652.0	220.0	165.4	59.4	56.4		109.0	109.0	51.2	50.7
	416µsec	546.0	144.0	87.8	22.1	19.2		31.3	31.3	13.5	13.8
1mA	16.67msec	608.0	324.0	167.0	121.0	56.3	55.0		108.6	50.6	50.4
	416µsec	488.0	205.0	85.6	43.2	19.0	17.7		31.3	13.7	14
10mA	16.67msec	727.0	280.0	224.5	118.6	116.0	54.8	54.8		51.0	51.6
	416µsec	567.0	162.0	111.0	41.4	38.8	17.5	17.6		13.6	14
100mA	16.67msec	666.0	380.0	219.0	182.4	114.0	112.0	53.2	53.2		50.4
	416µsec	504.0	223.5	102.5	61.2	36.6	34.9	15.7	15.6		13.75
1A	16.67msec	799	454	295	191.5	187.4	126	125	66.8	63.6	
	416µsec	594	261	132	89.2	70.2	50	49.4	30	27	

Note: Range change times are expressed in milliseconds.

Table 3-15. Typical V–measure Range Change Times (Fixed Range)

		To Range			
From Range	**Integration Time**	**1.1V, 1.5V**	**11V, 15V**	**110V**	**1100V**
1.1V, 1.5V	16.67msec		51.1	55.0	55.0
	416µsec		13.2	17.4	17.4
11V, 15V	16.67msec	52.9		55.0	55.0
	416µsec	14.8		17.4	17.4
110V	16.67msec	57.6	57.6		50.0
	416µsec	19.9	19.9		12.3
1100V	16.67msec	57.8	57.8	52.4	
	416µsec	19.9	19.9	14.8	

Note: Range change times are expressed in milliseconds.

Table 3-16. Typical V–measure Range Change Times (Autorange)

		To Range			
From Range	**Integration Time**	**1.1V, 1.5V**	**11V, 15V**	**110V**	**1100V**
1.1V, 1.5V	16.67msec		121.4	116.4	58.8
	416µsec		43.7	38.6	21.1
11V, 15V	16.67msec	50.4		116.2	59.0
	416µsec	15.4		38.7	20.9
110V	16.67msec	58.2	57.4		53.9
	416µsec	21.6	20.1		16.1
1100V	16.67msec	57.0	57.1	52.9	
	416µsec	20.1	20.1	15.5	

Note: Range change times are expressed in milliseconds.

3.7.3 Estimating Sweep Performance

The following text explains how to determine the time period from the sweep creation time until all data is transferred to the computer (see Figure 3-33). All times are typical, based on the average of at least ten sweep points, and are expressed in milliseconds. The formulas were derived using IEEE X as an input trigger to start the source phase. Instead of waiting for SRQ on sweep done, performance could be improved by requesting data immediately after triggering, but this would hang the bus.

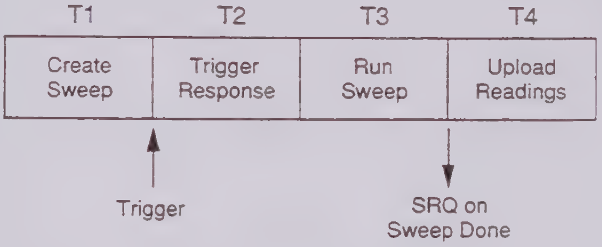


Figure 3-33. Sweep Measurement Times

Create Sweep Time (T1) — This is the time needed for a Model 236/237/238 to generate a sweep. It is dependent on the type of sweep (non-pulsed or pulsed) and the number of S-D-M cycles in the sweep (count). For fixed level, linear stair, and log stair sweeps:

$$T1 = (3.5\text{msec}) \times (\text{Count}) + 40\text{msec}$$

For fixed level pulsed, linear stair pulsed, and log stair pulsed sweeps:

$$T1 = (2.2\text{msec}) \times (\text{Count}) + 40\text{msec}$$

Trigger Response Time (T2) — This time is between the trigger event and the first sample point. It depends on the programmed trigger origin, with the fastest triggers being IEEE GET and an external trigger. Both are specified at <2msec.

Run Sweep Time (T3) — This is the time from the start of the sweep to generation of SRQ on sweep done. With the filter disabled and no source or measure range changes during the sweep, it is a function of the count (number of S-D-M cycles), the acquisition time (sum of default delay, sweep delay, and measure time), and the time needed to process a reading. Refer to Table 3-9 and Table 3-12 for listings of default delays and measure times.

If the acquisition time is $\geq$3.4msec, there is enough time to process a reading before the next acquisition and the run sweep time can be calculated by:

$$T3 = (\text{Count}) \times (\text{Acquisition time})$$

Where:

Count = Number of S-D-M cycles

Acquisition time = Default delay + Sweep delay + Measure time

If the acquisition time is $\leq$3.4msec, the process time must be added to the above equation, where process time is expressed as:

$$\text{Process time} = (\text{Count}) \times (3.4\text{msec} - \text{Acquisition time})$$

and then:

$$T3 = (\text{Count}) \times (\text{Acquisition time}) + (\text{Process time})$$

Source or measure range changes during a sweep lengthen the run sweep time and complicate calculations. To estimate the run sweep time, partition the sweep into segments where no range changes occur, calculate a run sweep time for each segment, and total the times. Also, from Table 3-11 and NO TAG through Table 3-16 and the previous discussion on range changing, determine the range change times. Note that the table entries for measure range change times include the measure times.

Upload Readings Time (T4) — Assuming that the controller can accept data as fast as the Model 236/237/238 can send it, the following equations quantify the time needed to upload all lines of sweep data for various output data formats:

G4,0,2 $T4 = (13.5\text{msec}) \times (\text{Count}) + 0.6\text{msec}$
Measure values
ASCII with prefix and suffix

G5,0,2 $T4 = (16.8\text{msec}) \times (\text{Count}) + 2.6\text{msec}$
Source and measure values
ASCII with prefix and suffix

G15,0,2 $T4 = (32.7\text{msec}) \times (\text{Count}) - 2.7\text{msec}$
All items
ASCII with prefix and suffix

G4,2,2 $T4 = (11.3\text{msec}) \times (\text{Count}) - 1.7\text{msec}$
Measure values
ASCII with no prefix or suffix

G5,2,2 $T4 = (13.0\text{msec}) \times (\text{Count}) + 3.6\text{msec}$
Source and measure values
ASCII with no prefix or suffix

G15,2,2 $T4 = (29.4\text{msec}) \times (\text{Count}) + 1.1\text{msec}$
All items
ASCII with no prefix or suffix

G4,3,2 or G4,4,2 $T4 = (0.77\text{msec}) \times (\text{Count}) + 3.1\text{msec}$
Measure values
HP or IBM binary

G5,3,2 or G5,4,2 $T4 = (1.2\text{msec}) \times (\text{Count}) + 3.2\text{msec}$
Source and measure values
HP or IBM binary

G15,3,2 or G15,4,2 $T4 = (2.0\text{msec}) \times (\text{Count}) + 2.7\text{msec}$
All items
HP or IBM binary

3.7.4 Estimating dc Performance

The times needed for dc operation are shown in Figure 3-34 and explained in the following paragraphs.

Command Transfer Time (T1) — DDCs are transferred at 5 characters per millisecond. A typical command to set bias level, range, and delay (B1,1,0X) has a T1 time of 1.4msec.

Command Execution Time (T2) — The execution time for the previous Bias Operation command is 25msec.

Delay Times (T3) — This time is the sum of the default delay, the user-programmable dc delay, and the range change time. Default delays are listed in Table 3-9. Range change times for autoranging are described in paragraph 3.7.2.

Measure Time (T4) — Measure times are dependent on the programmed integration time and are listed in Table 3-12.

Data Preprocess Time (T5) — This is the time needed for transferring a reading within the instrument and the application of cal constants to the reading. It is a constant 9msec per reading.

Upload Reading Time (T6) — Table 3-17 lists the times needed to upload one line of dc data for various items and output data formats.

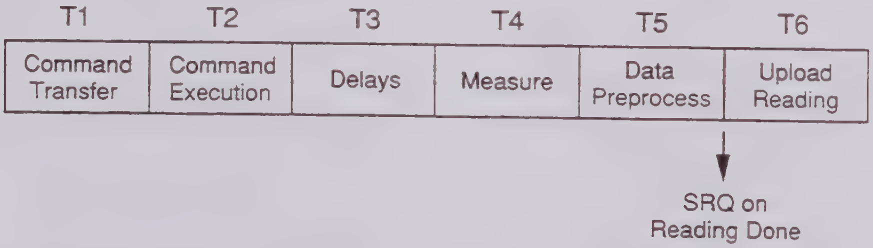


Figure 3-34. Single dc Measurement Times

Table 3-17. Dc Data Transfer Times

	Format		
Items	**ASCII Data with Prefix and Suffix**	**ASCII Data, no Prefix or Suffix**	**HP or IBM Binary Data**
Measure	18msec	13msec	4msec
Source and Measure	27msec	18msec	6.5msec
All	47msec	30msec	7msec

APPENDICES

APPENDIX A Device-dependent Command Summary
APPENDIX B Interface Function Codes
APPENDIX C ASCII Character Codes and IEEE-488 Multiline Interface Command Messages
APPENDIX D Controller Programs
APPENDIX E IEEE-488 Bus Overview

APPENDIX A
Device-dependent Command Summary

Table A-1. Device-dependent Command Summary

Mode	Command	Description	Para.
Modify Sweep List	A(level),(range),(delay), first(,last)	Modify sweep list points	3.6.1
Bias Operation	B(level),(range),(delay)	Select bias operation	3.6.2
Calibration	C step (,value) X	Calibrate instrument	3.6.3
Display	D0X	Return display to normal	
	D1,aaa...aX	Display ASCII characters (18 max.)	3.6.4
	D2,aaa...aX	Display and store ASCII characters (18 max.)	
Source and Function	F(source),(function)	Select source (V or I) and function (dc or sweep)	3.6.5
Output Data Format	G(items),(format),(lines)	Select items included, format, and lines per talk in output	3.6.6
IEEE Immediate Trigger	H0X	Cause an immediate bus trigger	3.6.7
Self-tests	J0X	Restore factory defaults	3.6.8
	J1X	Perform memory test	
	J2X	Perform display test	
EOI and Bus Hold-off	K0	Enable EOI, enable hold-off on X	3.6.9
	K1	Disable EOI, enable hold-off on X	
	K2	Enable EOI, disable hold-off on X	
	K3	Disable EOI, disable hold-off on X	
Compliance	L(level),(range)	Set compliance level and range	3.6.10
SRQ Mask and Serial Poll Byte	M(mask),(compliance)	Select conditions that will cause a service-request	3.6.11
Operate	N0	Place unit in standby mode	3.6.12
	N1	Place unit in operate mode	
Output Sense	O0	Select local sensing	3.6.13
	O1	Select remote sensing	
Filter	P0	Measurement filter disabled	3.6.14
	P1	2-reading filter	
	P2	4-reading filter	
	P3	8-reading filter	
	P4	16-reading filter	
	P5	32-reading filter	
Create/Append Sweep List	Q0,(level),(range),(delay), (count)	Create fixed level sweep	3.6.15
	Q1,(start),(stop),(step), (range),(delay)	Create linear stair sweep	

Mode	Command	Description	Para.
Create/Append Sweep List (Cont.)	Q2,(start),(stop),(points),(range),(delay)	Create logarithmic stair sweep	
	Q3,(level),(range),(pulses),(t_{ON}),(t_{OFF})	Create fixed level pulsed sweep	
	Q4,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})	Create linear stair pulsed sweep	
	Q5,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})	Create logarithmic stair pulsed sweep	
	Q6,(level),(range),(delay),(count)	Append fixed level sweep	
	Q7, (start),(stop),(step),(range),(delay)	Append linear stair sweep	
	Q8,(start),(stop),(points),(range),(delay)	Append logarithmic stair sweep	
	Q9,(level),(range),(pulses),(t_{ON}),(t_{OFF})	Append fixed level pulsed sweep	
	Q10,(start),(stop),(step),(range),(t_{ON}),(t_{OFF})	Append linear stair pulsed sweep	
	Q11,(start),(stop),(points),(range),(t_{ON}),(t_{OFF})	Append logarithmic stair pulsed sweep	
Trigger Control	R0	Disable input/output triggers	3.6.16
	R1	Enable input/output triggers	
Integration Time	S0	416µsec integration time	3.6.17
	S1	4msec integration time	
	S2	16.67msec integration time	
	S3	20msec integration time	
Trigger Configuration	T(origin),(in),(out),(end)	Program trigger origin, effect, output trigger time, and sweep end trigger	3.6.18
Status	U0	Send model no. and revision	3.6.19
	U1	Send error status word	
	U2	Send stored ASCII string	
	U3	Send machine status word	
	U4	Send measurement parameters	
	U5	Send compliance value	
	U6	Send suppression value	
	U7	Send calibration status word	
	U8	Send defined sweep size	
	U9	Send warning status word	
	U10	Send first sweep point in compliance	
	U11	Send sweep measure size	
1100V Range Control	V0	Disable 1100V range	3.6.20
	V1	Enable 1100V range	
Default Delay	W0	Disable default delay	3.6.21
	W1	Enable default delay	
Execute	X	Execute commands	3.6.22
Terminator	Y0	<CR><LF>	3.6.23
	Y1	<LF><CR>	
	Y2	<CR>	
	Y3	<LF>	
	Y4	None	
Suppress	Z0	Disable suppression	3.6.24
	Z1	Enable suppression	

APPENDIX B
Interface Function Codes

The interface function codes, which are part of the IEEE-488-1978 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 236/237/238 are listed in Table B-1. The codes define Model 236/237/238 capabilities as follows:

SH (Source Handshake Function) — SH1 defines the ability of the instrument to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function) — AH1 defines the ability of the instrument to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function) — The ability of the instrument to send data over the bus to other devices is provided by the T function. Instrument talker capabilities (T6) exist only after the instrument has been addressed to talk.

L (Listener Function) — The ability for the instrument to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities (L4) of the instrument exist only after it has been addressed to listen.

SR (Service Request Function) — SR1 defines the ability of the instrument to request service from the controller.

RL (Remote-Local Function) — RL1 defines the ability of the instrument to be placed in the remote or local modes.

PP (Parallel Poll Function) — The instrument does not have parallel polling capabilities (PP0).

DC (Device Clear Function) — DC1 defines the ability of the instrument to be cleared (initialized).

DT (Device Trigger Function) — The ability for the instrument to have its readings triggered is provided DT1.

C (Controller Function) — The instrument does not have controller capabilities (C0).

TE (Extended Talker Function) — The instrument does not have extended talker capabilities (TE0).

LE (Extended Listener Function) — The instrument does not have extended listener capabilities (LE0).

E (Bus Driver Type) — The instrument has open-collector bus drivers (E1).

Table B-1. Model 236/237/238 Interface Function Codes

Code	Interface Function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability.
T6	Talker (basic talker, serial poll, unaddressed to talk on LAG)
L4	Listener (basic listener, unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker capabilities
LE0	No Extended Listener capabilities

APPENDIX C
ASCII Character Codes and IEEE-488 Multiline Interface Command Messages

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	–	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	∩	MTA 30
95	5F	—	UNL

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60	∩	MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	|	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

* Message sent or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

APPENDIX D

Controller Programs

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you to send a device-dependent command string to the instrument and obtain and display a string from the instrument.

Programs for the following controllers are included:

- A BASIC program for an IBM PC/XT/AT with a Capital Equipment Corporation PC<>488 Interface (Keithley Model PC-488-CEC IEEE-488 Interface Card).
- A program written with the ASYST software package (available from Keithley Instruments) for an IBM PC/XT/AT with a Capital Equipment Corporation PC<>488 Interface.
- A BASIC program for an IBM PC/XT/AT with IOtech Driver488 Software.
- A BASIC program for an IBM PC/XT/AT with a National GPIB PC Interface.
- A BASIC program for a Hewlett-Packard Model 9000 Series 200/300 computer.

IBM PC/XT/AT with Capital Equipment Corporation PC<>488 Interface (Keithley PC-488-CEC)

Introduction

General information about controlling a Model 236/237/238 with an IBM PC/XT/AT computer and Capital Equipment Corporation PC<>488 interface is given here. Refer to the CEC PC<>488 Programming and Reference Manual for complete information.

Initializing the System

The first step in any program is to initialize the system using the INITIALIZE routine. This routine sets the primary IEEE-488 bus address of the PC<>488, specifies the type of controller to be used, and sends an interface clear (IFC) to the other devices on the bus.

After booting up the IBM using DOS and entering BASICA, the statements of program 1 can be used at the start of any program to initialize the system:

Line 30 sets the address of the PC<>488 to 21, however, any other valid address could be used as long as it does not conflict with the address of any other device on the bus.

Interface Basic Programming Statements

This paragraph covers the PC<>488 statements that are essential to Model 236/237/238 operation. A partial list of programming statements is contained in Table D-1. The IBM BASIC CALL statement is used to execute the desired action. Before a CALL routine can be used, BASIC needs to know the offset address of the routine. In the table, the first statement of each programming sequence defines the offset address of the CALL routine.

Example Program

The following program sends a command string from an IBM PC/XT/AT computer to the Model 236/237/238 and displays the response on the CRT. The computer must be equipped with a CEC interface card and DOS 2.0 (or later revision) operating system.

Directions

1. Using the front panel menu feature, set the primary IEEE-488 address of the Model 236/237/238 to 16.
2. With the power off, connect the Model 236/237/238 to the IEEE-488 interface card installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into interpretive BASIC language.
4. Enter the lines of Program 2 using the return key after each line.
5. Run the program and type in the desired command string at the ENTER COMMAND STRING? prompt. For example, to view the instrument model number and firmware revision, type in U0X and press the return key. The Model 236/237/238 firmware revision, e.g. 236A01, will then appear on the computer display. A single line of data (NSDCV+00.000E+00,B0000) will appear for DDCs that have no response.

```
PROGRAM                                   COMMENTS

10   DEF SEG=&HC400                       ' Memory offset.
20   INITIALIZE=0                         ' Offset address of routine
30   MY.ADDRESS%=21                       ' Set PC<>488 address.
40   CONTROLLER%=0                        ' Set for system control.
50   CALL INITIALIZE (MY.ADDRESS%,        ' Execute INITIALIZE routine.
     CONTROLLER%)
```

Program 1

```
PROGRAM                                            COMMENTS

10   DEF SEG=&HC400                                ' Memory address
20   INITIALIZE=0                                  ' Define call offsets
30   SEND=9:ENTER=21
40   MY.ADDRESS%=21                                ' Set PC<>488 address
50   INST.ADDRESS%=16                              ' Set 236/237/238 address
60   CONTROLLER%=0                                 ' Set for system control
70   CALL INITIALIZE (MY.ADDRESS%,                 ' Initialize system
     CONTROLLER%)
80   LINE INPUT "ENTER COMMAND                     ' Prompt for string
     STRING:";CMD$
90   CALL SEND (INST.ADDRESS%,CMD$,                ' Send command string
     STATUS%)
100  RESPONSE$=SPACE$(80)                          ' Make room for data
110  CALL ENTER (RESPONSE$,LENGTH%,                ' Get response from 236/237/238
     INST.ADDRESS%,STATUS%)
120  PRINT RESPONSE$                               ' Display response
130  GOTO 80                                       ' Repeat
140  END
```

Program 2

Table D-1. BASIC Statements Necessary to Send Bus Commands

Action	PC<>488 Statements
Transmit command string (CMD$) to device 16.	SEND=9 ADDRESS%=16 CALL SEND(ADDRESS%,CMD$,STATUS%)
Obtain string from device 16.	ENTER=21 ADDRESS%=16 RESPONSE$=SPACE$(50) CALL ENTER(RESPONSE$,LENGTH%,ADDRESS%,STATUS%)
Send GTL to device 16.	TRANSMIT=3 CMD$="LISTEN 16 GTL" CALL TRANSMIT(CMD$,STATUS%)
Send SDC to device 16.	TRANSMIT=3 CMD$="LISTEN 16 SDC" CALL TRANSMIT(CMD$,STATUS%)
Send DCL to all devices.	TRANSMIT=3 CMD$="LISTEN 16 DCL" CALL TRANSMIT(CMD$,STATUS%)
Send remote enable.	TRANSMIT=3 CMD$="REN LISTEN 16" CALL TRANSMIT(CMD$,STATUS%)
Serial poll device 16.	SPOLL=12 ADDRESS%=16 CALL SPOLL%(ADDRESS%,POLL%,STATUS%)

IBM PC/XT/AT with CEC PC<>488 Interface and ASYST Software Package

Introduction

ASYST contains data acquisition, analysis, and graphing software in three integrated modules. Minimum requirements for ASYST include: 512K RAM (640K recommended), math coprocessor, parallel port, hard drive, and DOS 2.0 (or later version) operating system.

For this example, an optional software module is required for IEEE–488 interfacing. The computer must also be equipped with a CEC interface card (PC<>488 Model 300 or 310, or 4×488).

The ASYST program listed here sends a command string from an IBM PC/XT/AT computer to the Model 236/237/238 and displays the response on the computer's CRT.

Directions

This procedure will help an ASYST user through the steps necessary for GPIB configuration, program entry, and program execution. Refer to the ASYST documentation for more detailed instructions.

1. Using the front panel menu key, set the primary IEEE-488 address of the Model 236/237/238 to 16.
2. With the power off, connect the Model 236/237/238 to the IEEE-488 interface card installed in the IBM computer.
3. Boot ASYST software from DOS. You will get an OK prompt.
4. Use the <F2> key to enter the Main Configuration Menu. In addition to the usual configuration requirements of ASYST, the GPIB must be configured.

   From the Overlay Configuration Menu, select overlays GPIB Master and Type 1 NEC GPIB Driver.

   From the GPIB Configuration Menu, select a bus number, board type (National GPIB-PC1 or GPIB-PC2 for ASYST 2.0, Capital – NEC uPD7210 model for ASYST 3.0), memory address (2B8), primary address (0), and interrupt line.

5. Save your changes and return to the OK prompt.
6. Use the command line editor (EDIT 236.DMO) to enter the following program. Save the program and exit the editor.
7. When prompted, load the program with the L key, or type LOAD 236.DMO from the OK prompt.
8. When the program loads properly, type MAIN from the OK prompt to start execution.
9. Type in the desired command string at the "Enter command string:" prompt. For example, to view the instrument model number and firmware revision, type in U0X and press the return key. The Model 236/237/238 firmware revision, e.g. 236A01, will then appear on the computer display. A single line of data (NSDCV+00.000E+00,B0000) will appear for DDCs that have no response.
10. Type <Control-Break> to exit the program loop of 236.DMO and return to the OK prompt. The program-defined words can be removed from the ASYST dictionary by typing FORGET 236.

```
PROGRAM                         COMMENTS

BUS.INIT                        \ Initialize bus
SEND.INTERFACE.CLEAR            \ Take control of bus
REMOTE.ENABLE.ON                \ Allow remote operation
SYNCHRONOUS.GPIB                \ Make sure ASYST is in sync. mode
?GPIB.DEVICES                   \ List controller parameters
16 GPIB.DEVICE 236              \ Set 236/237/238 address and name
    EOI.ON                      \ Enable end or identify
    EOS.ON                      \ Enable end of string terminator
    10 EOS.CHARACTER            \ Use LF terminator
    1000 TIMEOUT                \ Set timeout of 1sec
?GPIB.DEVICE                    \ List 236/237/238 parameters
100 STRING COMMAND              \ Allocate 100 bytes for user input
100 STRING RESPONSE             \ Allocate 100 bytes for 236/237/238 response

: GET.INPUT                     \ Definition for user input
CR .” ENTER COMMAND STRING:”    \ Prompt user
“INPUT COMMAND ”:=              \ Get DDCs
;

: MAIN                          \ Definition for main program
 BEGIN                          \ Start loop
 ME                             \ Make controller current device
 GET.INPUT                      \ Get DDCs from user
 236                            \ Make 236/237/238 current device
 COMMAND GPIB.WRITE             \ Send DDCs to 236/237/238
 RESPONSE GPIB.READ             \ Get response
 CR RESPONSE “TYPE              \ Display response
 AGAIN                          \ Return for more commands
;
```

IBM PC/XT/AT or PS/2 with IOtech Driver488 Software

Introduction

Driver488 software is an IEEE-488 driver for IBM PC and compatible computers. When combined with an IEEE-488 interface board, the package can control devices from languages including BASIC, Pascal, Fortran, and C. Driver488 software is compatible with:

- IOtech GP488B or GP488/2 boards
- National Instruments GPIB-PC, PCII, PCIIA, or PCIII boards
- Capital Equipment #01000-00300 board
- IBM GPIB Adapter

The following GWBASIC program sends a command string to the Model 236/237/238 and displays the instrument response on the CRT. The computer must be equipped with an IEEE-488 interface board, the DOS 3.00 (or later) operating system, and a language with DOS I/O capability. Driver488 controller software must be installed and configured as described in the instruction manual.

Directions

1. Using the front panel menu feature, set the primary address of the Model 236/237/238 to 16.
2. With power off, connect the Model 236/237/238 to the IEEE-488 interface installed in the IBM computer.
3. Type in GWBASIC on the computer and get into the Microsoft interpretive BASIC language.
4. Enter the lines below using the return key after each line.
5. Run the program and type in the desired command string at the COMMAND STRING prompt. For example, to view the instrument model number and firmware revision, type in U0X and press the return key. The Model 236/237/238 firmware revision, e.g. 236A01, will then appear on the computer display. A single line of data (NSDCV+00.000E+00,B0000) will appear for DDCs that have no response.

```
PROGRAM                                            COMMENTS

10   OPEN “\DEV\IEEEOUT” FOR OUTPUT AS #1          ’ Open file for output
20   IOCTL#1, “BREAK”                              ’ Reset
30   PRINT#1,“RESET”
40   OPEN “\DEV\IEEEIN” FOR INPUT AS #2            ’ Open file for input
50   PRINT#1,“FILL ERROR”                          ’ Enable SEQUENCE error detect
60   LINE INPUT “COMMAND STRING: ”,A$              ’ Prompt for and get DDCs
70   IF LEN(A$)=0 THEN 130                         ’ Check for null
80   PRINT #1,“OUTPUT 16;”+A$                      ’ Address 236/237/238 to listen, send DDCs
90   PRINT #1,“ENTER 16”                           ’ Address 236/237/238 to talk
100  LINE INPUT#2,B$                               ’ Get response
110  PRINT B$                                      ’ Display response string
120  GOTO 60                                       ’ Repeat
130  END
```

IBM PC/XT/AT with National GPIB PC Interface

Introduction

The following program sends a command string to the Model 236/237/238 from an IBM PC/XT/AT computer and displays the instrument reading string on the CRT. The computer must be equipped with the National GPIB PC Interface and the DOS 2.00 (or later revision) operating system. Interface software must be installed and configured as described in the instruction manual.

Directions

1. Using the front panel program feature, set the primary address of the Model 236/237/238 to 16.
2. With the power off, connect the Model 236/237/238 to the IEEE-488 interface installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Place the interface software disk in the default drive, type LOAD"DECL", and press the return key.
5. Add the lines below to line 1-6 which are now in memory. Modify the address in lines 1 and 2, as described in the National instruction manual.
6. Run the program and type in the desired command string. For example, to view the instrument model number and firmware revision, type in U0X and press the return key. The Model 236/237/238 firmware revision, e.g. 236A01, will then appear on the computer display. A single line of data (NSDCV+00.000E+00,B0000) will appear for DDCs that have no response.

```
PROGRAM                                      COMMENTS

10    CLS                                    Clear screen.
20    NA$="GPIB0":CALL IBFIND(NA$,BRD0%)     Find board descriptor.
30    NA$="DEV1":CALL IBFIND(NA$,M236%)      Find instrument descriptor.
40    V%=16:CALL IBPAD(M236%,V%)             Set primary address to 16.
50    V%=&H102:CALL IBPOKE(BRD0%,V%)         Set timeouts.
60    V%=1:CALL IBSRE(BRD0%,V%)              Set REN true.
70    INPUT "COMMAND STRING";CMD$            Prompt for command.
80    IF CMD$="EXIT" THEN 150                See if program is to be halted.
90    IF CMD$="" THEN 70                     Check for null input.
100   CALL IBWRT (M236%,CMD$)                Address 236/237/238 to listen, send string.
110   RD$=SPACE$(100)                        Define reading input buffer.
120   CALL IBRD(M236%,RD$)                   Address 236/237/238 to talk, get reading.
130   PRINT RD$                              Display the string.
140   GOTO 70                                Repeat.
150   V%=0:CALL IBONL(M236%,V%)              Close the instrument file.
160   CALL IBONL(BRD0%,V%)                   Close the board file.
170   END
```

Hewlett-Packard Model 9000 Series 200/300

Introduction

The following program sends a command string to the Model 236/237/238 from a Hewlett-Packard Model 9000 Series 200/300 computer and displays the response on the computer CRT. The computer must be equipped with HP BASIC 4.0.

Directions

1. Using the front panel menu feature, set the primary IEEE-488 address of the Model 236/237/238 to 16.
2. With the power off, connect the Model 236/237/238 to the IEEE-488 interface card installed in the HP computer.
3. Enter the lines in the program below, using the ENTER/RETURN key after each line.
4. Press the RUN key and type in the desired command string at the COMMAND STRING prompt. For example, to view the instrument model number and firmware revision, type in U0X and press the ENTER/RETURN key. The Model 236/237/238 firmware revision, e.g. 236A01, will then appear on the computer display. A single line of data (NSDCV+00.000E+00,B0000) will appear for DDCs that have no response.

```
PROGRAM                                 COMMENTS

10  DIM A$[50],B$[50]
20  REMOTE 716                          ! Place 236/237/238 in remote.
30  LINPUT "COMMAND STRING:",A$         ! Prompt for and input command.
40  OUTPUT 716;A$                       ! Address 236/237/238 to listen, send string.
50  ENTER 716;B$                        ! Address 236/237/238 to talk, input response.
60  PRINT B$                            ! Display response string.
70  GOTO 30                             !  Repeat
80  END
```

APPENDIX E
IEEE-488 Bus Overview

Introduction

Basically, the IEEE-488 bus is simply a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves to supervise the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which device will listen. As a talker, a device will output information and as a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each one.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. The devices that need to listen to the talker are addressed to listen by the controller. Each listener is then referred to as an active listener. Devices that do not need to listen are instructed to unlisten. The reason for the unlisten instruction is to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is as follows:

1. The listener indicates that it is read to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being, sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

Bus Description

The IEEE-488 bus, which is also frequently referred to a the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical set up for controlled operation is shown in Figure E-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker and listener. The controller does what its name implies; it controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only or both a talker and listener.

There are two categories of controllers: system controller, and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 31, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For exam-

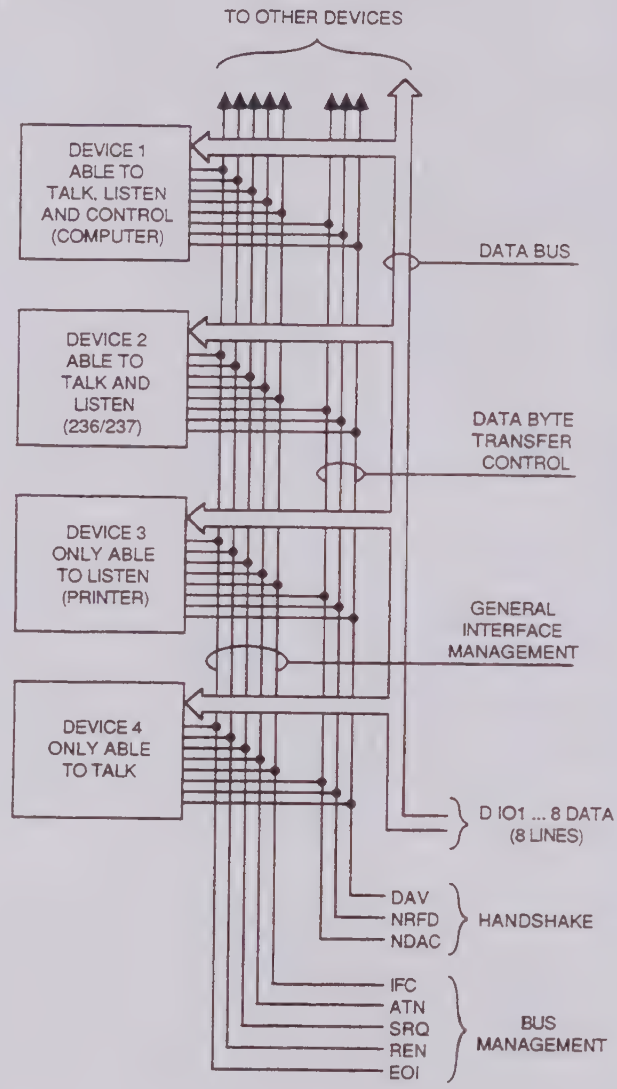

TO OTHER DEVICES
DEVICE 1 ABLE TO TALK, LISTEN AND CONTROL (COMPUTER)
DEVICE 2 ABLE TO TALK AND LISTEN (236/237)
DEVICE 3 ONLY ABLE TO LISTEN (PRINTER)
DEVICE 4 ONLY ABLE TO TALK
DATA BUS
DATA BYTE TRANSFER CONTROL
GENERAL INTERFACE MANAGEMENT
D IO1 ... 8 DATA (8 LINES)
DAV
NRFD
NDAC
HANDSHAKE
IFC
ATN
SRQ
REN
EOI
BUS MANAGEMENT

Figure E-1. IEEE-488 Bus Configuration

ple, if the primary address is 16 decimal ($10), the actual listen address is $30 ($30 = $10 + $20). In a similar manner, the talk address is obtained by ORing the primary address with $40. With the present example, the talk address derived from a primary address of 16 decimal would be $50 ($50 = $10 + $40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however, that many devices, including the Model 236/237/238, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example: if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information and the appropriate software can be used to direct the information to the desired location.

Bus Lines

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

Data Lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bidirectional. The data lines operate with low true logic.

Bus Management Lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

ATN (Attention) — The ATN line is one of the more important management lines in that the state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear) — As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable) — The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify) — The EOI is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request) — This line is used by device when they require service from the controller.

Handshake Lines

The bus handshake lines that operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (DATA VALID) — The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data) — The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDCA (Not Data Accepted) — NDCA is also controlled by the accepting device. The state of NDCA tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure E-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The sequence just described is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses or commands as described in the following paragraph.

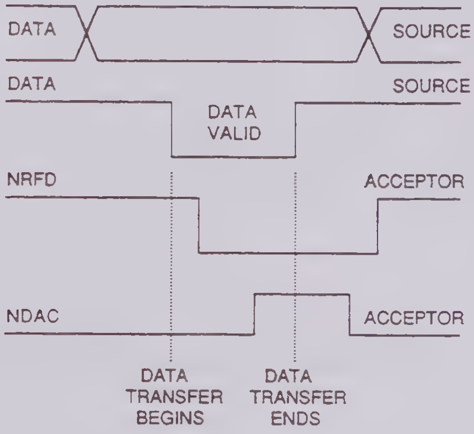


Figure E-2. IEEE-488 Handshake Sequence

Bus Commands

The instrument may be given a number of special bus commands through the IEEE-488 interface. This section briefly describes the purpose of the bus commands which are grouped into the following three categories.

1. Uniline Commands - Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
2. Multiline Commands - General bus commands which are sent over the data lines with the ATN line true (low).
3. Device-dependent Commands - Special commands whose meanings depend on device configurations; sent with ATN high (false).

These bus commands and their general purpose are summarized in Table E-1.

Uniline Commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a de-

Table E-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent		High	Programs Model 236/237/238 for various modes.

* X = Don't Care

scription of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable) — REN is sent to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End or Identify) — EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear) — IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention) — The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request) — SRQ is asserted by a device when it requires service from a controller.

Universal Multiline Commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the commands is transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout) — LLO is sent to the instrument to lock out their front panel controls.

DCL (Device Clear) — DCL is used to return instruments to some default state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable) — SPE is the first step in the serial polling sequence which is used to determine which device has requested service.

SPD (Serial Poll Disable) — SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed Multiline Commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the commands and the address preceding it are sent with ATN true.

SDC (Selective Device Clear) — The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local) — The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO commands.

GET (Group Execute Trigger) — The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

LAG (Listen Address Group) — These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group) — The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group) — Commands in this group provide additional addressing capabilities. Many devices (including the Model 236/237/238) do not use these commands.

Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten) — Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk) — Any previously commanded talkers will be placed in the talker idle state by the UNT command.

Device-dependent Commands

The purpose of the device-dependent commands will depend on the configuration of the instrument. Generally, these commands are sent as one or more ASCII characters that tell the device to perform a specific function.

The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure E-3. Hexadecimal and the decimal values for the various commands are listed in Table E-2.

D_7 D_6 D_5 D_4						X 0 0 0	COMMAND	X 0 0 1	COMMAND	X 0 1 0	PRIMARY ADDRESS	X 0 1 1	PRIMARY ADDRESS	X 1 0 0	PRIMARY ADDRESS	X 1 0 1	PRIMARY ADDRESS	X 1 1 0		X 1 1 1	
Bits	D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
	0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
	0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
	0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
	0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	c		s	
	0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
	0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
	0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
	0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
	1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
	1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
	1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
	1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
	1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
	1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
	1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		~	
	1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE), PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 236/237/238.

NOTE: D_0 = DIO1 . . . D_7 = DIO8
X = DON'T CARE

Figure E-3. Command Codes

Table E-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SGG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table E-3 lists a typical bus sequence for sending the addressed multiline commands. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table E-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

IEEE Command Groups

Command groups supported by the Model 236/237/238 are listed in Table E-5. Device-dependent commands are not included in this list.

Table E-3. Typical Addressed Command Sequence

			Data Bus		
Step	**Command**	**ATN State**	**ASCII**	**Hex**	**Decimal**
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	0	30	48
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 16.

Table E-4. Typical Device-dependent Command Sequence

			Data Bus		
Step	**Command**	**ATN State**	**ASCII**	**Hex**	**Decimal**
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	0	30	48
3	Data	Set high	F	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 16.

Table E-5. IEEE Command Group

HANDSHAKE COMMAND GROUP
NDAC = NOT DATA ACCEPTED
NRFD = NOT READY FOR DATA
DAV = DATA VALID
UNIVERSAL COMMAND GROUP
ATN = ATTENTION
DCL = DEVICE CLEAR
IFC = INTERFACE CLEAR
REN = REMOTE ENABLE
SPD = SERIAL POLL DISABLE
SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP
LISTEN: LAG = LISTEN ADDRESS GROUP
MLA = MY LISTEN ADDRESS
UNL = UNLISTEN
TALK: TAG = TALK ADDRESS GROUP
MTA = MY TALK ADDRESS
UNT = UNTALK
OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP
ACG = ADDRESSED COMMAND GROUP
GTL = GO TO LOCAL
SDC = SELECTIVE CLEAR
STATUS COMMAND GROUP
RQS = REQUEST SERVICE
SRQ = SERIAL POLL REQUEST
STB = STATUS BYTE
EOI = END

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KEITHLEY

Service Form

Model No. ____________________ **Serial No.** ____________________ **Date** ____________

Name and Telephone No. ____

Company ____

List all control settings, describe problem and check boxes that apply to problem. ____________________

____

____

☐ Intermittent
☐ IEEE failure
☐ Front panel operational
☐ Analog output follows display
☐ Obvious problem on power-up
☐ All ranges or functions are bad
☐ Particular range or function bad; specify ____________________
☐ Batteries and fuses are OK
☐ Checked all cables

Display or output (check one)

☐ Drifts
☐ Unstable
☐ Overload
☐ Unable to zero
☐ Will not read applied input

☐ Calibration only
☐ Data required
☐ Certificate of calibration required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

____

____

What power line voltage is used? ________________________ Ambient temperature? __________________°F

Relative humidity? ______________________ Other? ____

Any additional information. (If special modifications have been made by the user, please describe.)

____

____

Be sure to include your name and phone number on this service form.

KEITHLEY

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

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